# Minerals Yearbook

## 1985

## *Volume I*

## METALS AND MINERALS

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849

*Prepared by staff of the*

BUREAU OF MINES

**UNITED STATES DEPARTMENT OF THE INTERIOR • Donald Paul Hodel, Secretary**

**BUREAU OF MINES • Robert C. Horton, Director**

**As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.**

**U.S. GOVERNMENT PRINTING OFFICE**

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**Washington, D.C. 20402**

# Foreword

This edition of the Minerals Yearbook discusses the performance of the worldwide minerals industry during 1985 and provides background information to assist in interpreting developments during the year being reviewed. Content of the individual volumes follows:

Volume I, Metals and Minerals, contains chapters on virtually all metallic and nonmetallic mineral commodities important to the U.S. economy. In addition, it includes a statistical summary chapter, a chapter on mining and quarrying trends, and a chapter discussing the statistical surveying methods used by the Bureau of Mines.

Volume II, Area Reports: Domestic, contains chapters on the mineral industry of each of the 50 States, the U.S. island possessions in the Pacific Ocean and the Caribbean Sea, and the Commonwealth of Puerto Rico. This volume also has a statistical summary.

Volume III, Area Reports: International, contains the latest available mineral data on more than 150 foreign countries and discusses the importance of minerals to the economies of these nations. A separate chapter reviews the international minerals industry in general and its relationship to the world economy.

The Bureau of Mines continually strives to improve the value of its publications to users. Therefore, constructive comments and suggestions by readers of the Yearbook will be welcomed.

Robert C. Horton, *Director*

# Acknowledgments

Volume I, Metals and Minerals, of the Minerals Yearbook, presents data on about 90 mineral commodities that were obtained as a result of the mineral information gathering activities of the Bureau of Mines.

The collection, compilation, and analysis of domestic minerals industries data were performed by the staffs of the Divisions of Ferrous Metals, Nonferrous Metals, and Industrial Minerals of the Assistant Directorate, Minerals Information. Statistical data were compiled from information supplied by mineral producers and consumers in response to canvasses, and their voluntary response is gratefully appreciated. Information obtained from individual firms by means of Bureau of Mines canvasses has been grouped to provide statistical aggregates. Data on individual firms are presented only if available from published or other nonproprietary sources or when permission of the respondent has been granted.

The chapter "Nonfuel Minerals Survey Methods" discusses in somewhat greater detail procedures for canvassing the minerals industry and the processing and evaluation of these data.

Other material appearing in this volume was obtained from the trade and technical press, industry contacts, and other sources, and this cooperation is gratefully acknowledged.

Statistics on world production were compiled in the Branch of Geographic Data, Division of International Minerals from numerous sources including reports from the U.S. Department of State. U.S. foreign trade data were obtained from reports of the Bureau of the Census, U.S. Department of Commerce.

The Branches of Publication Support Services and Editorial Services, Division of Publication, provided general guidance on the preparation and coordination of the chapters in this volume and reviewed the manuscripts to insure statistical consistency among the tables, text, and figures between this volume and other volumes, and between this edition and those of former years.

The Bureau of Mines has been assisted in collecting mine production data and other supporting information by numerous cooperating State agencies. These organizations are listed in the acknowledgments to Volume II.

Albert E. Schreck, *Chief, Division of Publication*

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# Nonfuel Minerals Survey Methods

### By Staff, Office of Statistical Standards

The Bureau of Mines Minerals Information organization collects worldwide data on virtually every commercially important nonfuel mineral commodity. These data form the base for tracking and assessing the health of the minerals sector of the U.S. economy.

This data collection activity was instituted by the 47th Congress in an appropriations act of August 7, 1882 (22 Stat. 329), to place the collection of mineral statistics on an annual basis. The most recent authority for the Bureau of Mines Minerals Information activity is the National Materials and Minerals Policy, Research and Development Act of 1980 (Public Law 96-479, 96th Congress), which strengthens protection for proprietary data provided to the U.S. Department of the Interior by persons or firms engaged in any phase of mineral or mineral-material production or consumption.

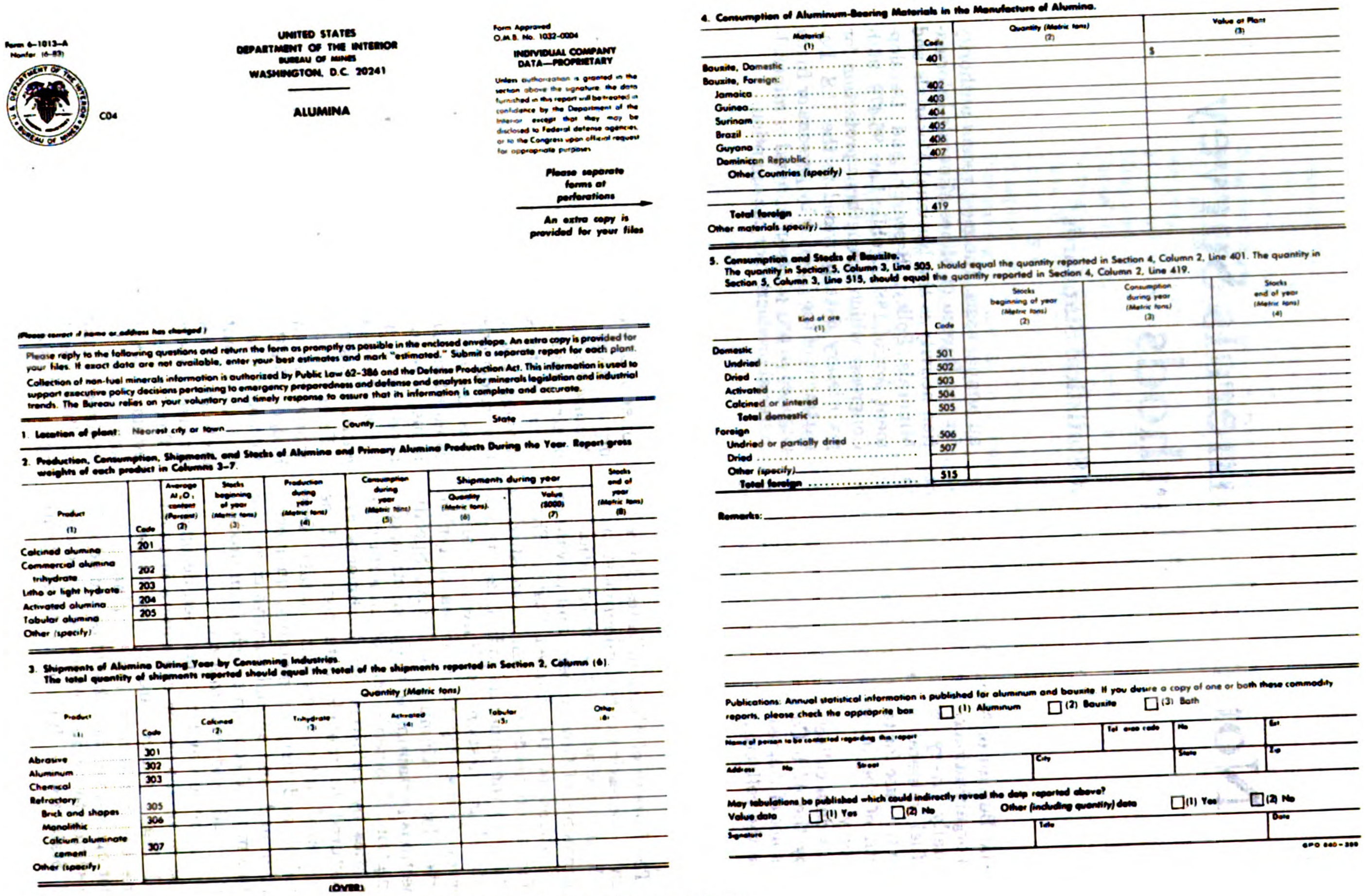
## DATA COLLECTION SURVEYS

The Bureau of Mines initiates the collection of domestic nonfuel minerals statistics with an appraisal of the information requirements of Government and private organizations of the United States. Those information needs that can be satisfied by data from the minerals industries are formulated as questions on Bureau of Mines survey forms. Figure 1 shows a typical survey form, Alumina (6-1013-A). Specific questions pertaining to the production, consumption, shipments, etc., of mineral commodities by industrial establishments are structured to provide data that will be aggregated into meaningful totals. One hundred and sixty-six monthly, quarterly, semiannual, and annual surveys cover the entire mineral economic cycle from production to trade and consumption.

Once the survey form has been designed, a list of producers or consumers is developed. Many sources are utilized to determine the companies, mines, plants, and other operations that should be included in the survey to produce meaningful national and State totals. Bureau of Mines State Mineral Officers, State geologists, Federal organizations (e.g., Mine Safety and Health Administration), trade associations, and industry publications and directories are some of the sources that are explored to develop and update survey listings. With few exceptions, an attempt is made to canvass the entire population of appropriate establishments. The iron and steel scrap industry is an example of one of the exceptions where a sampling plan is employed rather than a complete canvass of the entire industry.

Prior to mailing, the survey form must be approved by the Office of Management and Budget (OMB). Under the Paperwork Reduction Act of 1980, OMB approves the need or requirement for collecting the data and protects industry from unwarranted Government paperwork.

The Bureau publishes a "Survey Forms Catalog," which describes the content of each survey. Copies of the catalog may be obtained by contacting the Office of Statistical Standards, U.S. Bureau of Mines, Washington, DC 20241.



Form 6-1013-A
Nonfer. (6-83)

C04

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON, D.C. 20241

ALUMINA

Form Approved
O.M.B. No. 1032-0004

INDIVIDUAL COMPANY
DATA—PROPRIETARY

Unless authorization is granted in the section above the signature, the data furnished in this report will be treated in confidence by the Department of the Interior except that they may be disclosed to Federal defense agencies, or to the Congress upon official request for appropriate purposes.

Please separate forms at perforations

An extra copy is provided for your files

(Please correct if name or address has changed.)

Please reply to the following questions and return the form as promptly as possible in the enclosed envelope. An extra copy is provided for your files. If exact data are not available, enter your best estimates and mark "estimated." Submit a separate report for each plant. Collection of non-fuel minerals information is authorized by Public Law 62-386 and the Defense Production Act. This information is used to support executive policy decisions pertaining to emergency preparedness and defense and analyses for minerals legislation and industrial trends. The Bureau relies on your voluntary and timely response to assure that its information is complete and accurate.

1. Location of plant: Nearest city or town ______ County ______ State ______

2. Production, Consumption, Shipments, and Stocks of Alumina and Primary Alumina Products During the Year. Report gross weights of each product in Columns 3–7.

| Product (1) | Code | Average $Al_2O_3$ content (Percent) (2) | Stocks beginning of year (Metric tons) (3) | Production during year (Metric tons) (4) | Consumption during year (Metric tons) (5) | Shipments during year: Quantity (Metric tons) (6) | Shipments during year: Value ($000) (7) | Stocks end of year (Metric tons) (8) |
|---|---|---|---|---|---|---|---|---|
| Calcined alumina | 201 | | | | | | | |
| Commercial alumina trihydrate | 202 | | | | | | | |
| Litho or light hydrate | 203 | | | | | | | |
| Activated alumina | 204 | | | | | | | |
| Tabular alumina | 205 | | | | | | | |
| Other (specify) | | | | | | | | |

3. Shipments of Alumina During Year by Consuming Industries.
The total quantity of shipments reported should equal the total of the shipments reported in Section 2, Column (6).

| Product (1) | Code | Quantity (Metric tons): Calcined (2) | Trihydrate (3) | Activated (4) | Tabular (5) | Other (6) |
|---|---|---|---|---|---|---|
| Abrasive | 301 | | | | | |
| Aluminum | 302 | | | | | |
| Chemical | 303 | | | | | |
| Refractory: | | | | | | |
| Brick and shapes | 305 | | | | | |
| Monolithic | 306 | | | | | |
| Calcium aluminate cement | 307 | | | | | |
| Other (specify) | | | | | | |

(OVER)

4. Consumption of Aluminum-Bearing Materials in the Manufacture of Alumina.

| Material (1) | Code | Quantity (Metric tons) (2) | Value at Plant (3) |
|---|---|---|---|
| Bauxite, Domestic | 401 | | $ |
| Bauxite, Foreign: | | | |
| Jamaica | 402 | | |
| Guinea | 403 | | |
| Surinam | 404 | | |
| Brazil | 405 | | |
| Guyana | 406 | | |
| Dominican Republic | 407 | | |
| Other Countries (specify) | | | |
| | | | |
| | | | |
| Total foreign | 419 | | |
| Other materials specify) | | | |

5. Consumption and Stocks of Bauxite.
The quantity in Section 5, Column 3, Line 505, should equal the quantity reported in Section 4, Column 2, Line 401. The quantity in Section 5, Column 3, Line 515, should equal the quantity reported in Section 4, Column 2, Line 419.

| Kind of ore (1) | Code | Stocks beginning of year (Metric tons) (2) | Consumption during year (Metric tons) (3) | Stocks end of year (Metric tons) (4) |
|---|---|---|---|---|
| Domestic | | | | |
| Undried | 501 | | | |
| Dried | 502 | | | |
| Activated | 503 | | | |
| Calcined or sintered | 504 | | | |
| Total domestic | 505 | | | |
| Foreign | | | | |
| Undried or partially dried | 506 | | | |
| Dried | 507 | | | |
| Other (specify) | | | | |
| Total foreign | 515 | | | |

Remarks: ______

Publications: Annual statistical information is published for aluminum and bauxite. If you desire a copy of one or both these commodity reports, please check the appropriate box ☐ (1) Aluminum ☐ (2) Bauxite ☐ (3) Both

Name of person to be contacted regarding this report ______ Tel. area code ______ No. ______ Ext. ______

Address No. ______ Street ______ City ______ State ______ Zip ______

May tabulations be published which could indirectly reveal the data reported above?
Value data ☐ (1) Yes ☐ (2) No Other (including quantity) data ☐ (1) Yes ☐ (2) No

Signature ______ Title ______ Date ______

GPO 840-389

Figure 1.—A typical survey form.

## SURVEY PROCESSING

The 166 surveys yield more than 60,000 responses from approximately 27,000 establishments annually. Each of the completed survey forms returned to the Bureau undergoes extensive scrutiny to ensure the highest level of accuracy possible in recording mineral data. Bureau specialists ensure that no error is introduced owing to reporting in units other than those specified on the survey form. Relationships between related measures such as crude ore produced and marketable product are analyzed for consistency. Internal numerical relationships such as column and row totals are checked. The data reported in the current reporting period are checked against prior reports to detect possible errors or omissions.

For automated surveys, the specialist reviews the form for correctness and completeness before the data are entered into the computer. The computer is programed to conduct a series of automated edit checks to ensure mathematical consistency and to identify any discrepancies between the data reported and logically acceptable responses.

The Bureau of Mines is modernizing and automating all of its survey processing methods. Automation of the commodity data subsystems supports the processing of individual surveys and the preparation of statistical tables for publication. A central data base includes the minerals data gathered through surveys as well as pertinent data from other sources. The data base enables Bureau specialists to retrieve the data required for analysis of minerals problems and for answering specific user questions.

**Survey Responses.**—To enable the reader to better understand the basis on which the statistics were calculated, each commodity chapter of the "Minerals Yearbook" includes a section entitled "Domestic Data Coverage." This section briefly describes the data sources, the number of establishments surveyed, the response percentage, and the method of estimating the production (or consumption) that is accounted for by nonrespondents.

Although the response to Bureau surveys is generally very good, the Bureau must employ an efficient procedure for handling instances of nonresponse in order to produce reliable aggregated data. Second mailings of the survey form may be made. Followup by telephone is employed extensively to provide complete data entries on the survey forms, to verify questionable entries, and also to encourage those not reporting to either complete and return survey forms or provide the information orally. Periodic visits to important minerals establishments are also made by Bureau commodity specialists or State Mineral Officers. These visits are made to gather missing data and also to point out the importance of the companies' reporting to the production of accurate national as well as State and county statistics. By showing the use of these statistics and the impact of nonresponse, the Bureau hopes to encourage as complete and accurate a canvass as possible.

The OMB "Guidelines for Reducing Reporting Burden" stipulates that the minimum acceptable response rate shall be 75% of the panel surveyed. In addition, the Bureau strives for a minimum reporting level of 75% of the quantity produced or consumed (depending on the survey) for certain key statistics. Response rates are periodically reviewed, and for those surveys not meeting the minimum reporting level, plans are developed and implemented to improve response rates.

**Estimation for Nonresponse.**—When efforts to obtain response to a Bureau survey fail, it is necessary to employ estimation or imputation techniques to account for the missing data. These techniques are most effective when the response rate is relatively high. The Bureau is continually striving to develop and make use of the most effective techniques. Some of the imputation methods depend only on knowledge of the prior reporting of the establishment, while others rely on external information to estimate the missing data. Survey forms received after publication cutoff dates are edited, and necessary imputations are made for missing data. The data base is updated, and these revisions will be reflected in subsequent publications.

**Protection of Proprietary Data.**—The Bureau of Mines relies on the cooperation of the U.S. minerals industry to provide the minerals data that are presented in this and other Bureau publications. Without substantial response to survey requests, the Bureau would not be able to present reliable statistics. The Bureau in turn respects the proprietary nature of the data received from the individual companies and establishments. To ensure that proprietary rights will not be violated, the Bureau analyzes each of the aggregated statistics to ascertain if the statistics of an individual company or establishment can be deduced from the aggregated statistics. For example, if there are only two significant producers of a commodity in a given State, the Bureau will not publish the total for the State since either large producer could readily estimate the production of the other. It is this obligation to protect proprietary information that results in the "Withheld" or "W" entries in "Minerals Yearbook" tables. When the company gives permission in writing, the Bureau may release data otherwise withheld because of proprietary considerations.

## FOREIGN DATA

Volume I of the "Minerals Yearbook" contains a "World Review" section in each commodity chapter that usually includes a world production table. These tables are prepared in the Bureau's Division of International Minerals. These data are gathered from various sources including published reports of foreign government mineral and statistical agencies, the U.S. Department of State, or international organizations such as the United Nations and the Organization of Petroleum Exporting Countries. Missing data are estimated by the country specialist based upon information gatherod from a variety of sources.

## PUBLICATIONS AND DATA SERVICES

In addition to the three volumes of the "Minerals Yearbook," the statistical data collected are published in other reports, the principal series being the "Mineral Industry Surveys." Mineral Industry Surveys are concise monthly, quarterly, or annual reports that contain timely statistical and economic data on nonfuel mineral commodities. The surveys are designed to keep Government agencies, the minerals industries, and the business community regularly informed of trends in production, distribution, inventories, and consumption of nonfuel minerals.

One of the earliest publications containing information on mineral production, resources, reserves, imports, exports, uses, recycling, substitution, environmental considerations, and related subjects is "Mineral Commodity Summaries." Published in January, it covers approximately 90 mineral commodities for the previous calendar year.

"Mineral Facts and Problems" is a one-volume reference book containing worldwide production information and demand forecasts for all nonfuel minerals. It is published every 5 years. In the 1985 edition, each commodity chapter covers the structure of the industry, uses of the commodity, reserves and resources, technology, supply-demand relationships, byproducts and coproducts, strategic considerations, economic and operating factors, and forecasts to 1990 and 2000. Each chapter also compares U.S. and world reserves with cumulative demand to appraise the adequacy of world mineral supplies.

The "Mineral Perspectives" series reports on the mineral resources, industries, and related infrastructure of those foreign countries or regions of the world that assume major importance to our Nation's mineral needs.

"Minerals and Materials/A Bimonthly Survey" provides timely information on selected commodities. Data and analyses are presented that are germane to policy issues of current interest. Brief narratives are supplemented by statistical graphs and tables. Data are provided for the current month and the previous 22 months, and estimates are made for the upcoming month.

The "Minerals Yearbook" and "Mineral Facts and Problems" are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. For additional information on the other Bureau publications, contact the Division of Publication, U.S. Bureau of Mines, 4900 LaSalle Road, Avondale, MD 20782.

Two types of machine readable (computer compatible) data are provided. A 10-year time series of domestic supply-demand relationships data on each commodity is available on 5-1/4-inch floppy disks from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161. These disks are compatible with many types of microcomputers and popular microcomputer application software packages. These data have been published every

5 years in "Mineral Facts and Problems" and are being updated annually in "Mineral Industry Surveys" and on the floppy disks. Copies of Bureau survey mailing lists are also available on magnetic tape or in printed form. These lists include the company and plant names, Standard Industrial Classification (SIC) codes, and the addresses to which the survey forms are mailed. Information on purchasing copies of mailing lists can be obtained from the Office of Statistical Standards, U.S. Bureau of Mines, 2401 E Street, NW., Washington, DC 20241.

# Mining and Quarrying Trends in the Metals and Industrial Minerals Industries

### By Thomas W. Martin, Daniel L. Edelstein, and Garrett H. Hyde

## MINING AND QUARRYING TRENDS[1]

This chapter includes tables from 1984 that were not available in time for publication of the 1984 Minerals Yearbook, but does not include corresponding tables for 1985. The value of raw nonfuel minerals produced in the United States during 1985 was estimated at $23.2 billion, an increase of $0.07 billion over the value for 1984. This is the third consecutive year that the value has increased, and except for a decrease in 1982, the value for each year has increased since 1971, or 13 out of 14 years. However, while the value of industrial minerals production continued to grow, reflecting the growth of the domestic economy, the value of metal mine production decreased in 1985 by 6%. This drop was more than offset by a 3% increase in the value of industrial minerals production because the value of industrial minerals produced was more than three times larger than the value of metals. The decrease makes 1985 the third year in the past 5 years in which a drop in the value of metal mining production occurred in the United States where production continued to lag behind growing world production. Domestic production of such major commodities as aluminum, copper, iron ore, phosphate rock, and zinc continued to decline owing to a number of international and domestic factors. Gold continued to be the most active commodity in the domestic metal mining industry. Despite lower prices, gold output increased to 2.5 million troy ounces, a 19% increase over that of 1984. The estimated annual production capacity of new gold mines beginning production exceeded 1 million ounces.

Overproduction by nations that rely on export of mineral commodities to support their economies and service their international debt; the strong value of the dollar relative to that of other currencies, which favors imported products; relatively high domestic labor costs compared with those of developing nations; and the use of industrial minerals such as carbon fibers, glass fibers, and plastics in products historically constructed from metals have all contributed to create chronically depressed world metal prices and markets in which the U.S. producer finds it increasingly difficult to compete. As a result, the U.S. mining industry continues to operate in a transitional state with many companies forced to retrench by closing or selling properties and assets, reducing employment, and renegotiating labor contracts. The mines that continue to operate have developed improved mining methods and operating techniques, and many have embarked on modernization programs in order to survive. Virtually every mining operation in the United States today has undergone substantial change over the past 5 years, and the mining industry is working harder and more effectively as indicated by the continuing gain in productivity. This demand for cost and productivity improvement is, in turn, fueling the development of new technology. The result has been numerous small improvements as well as some potentially major new developments.

Legislation and Government Programs.—Two laws were passed in 1985 providing for the minting of gold or silver coins. In July, the Statue of Liberty-Ellis Island Commemorative Coin Act was signed by the President. This bill provides for the minting of silver and gold coins in commemoration of the centennial of the Statue of Liberty. The other law, the Gold Bullion Coin Act of 1985, provides for the minting of gold coins to compete with the South African krugerrand and specifies the use of newly mined gold from natural deposits in the United States.

Legislation was introduced in Congress designating lands in seven areas for inclusion in the National Wilderness Preservation System. Only one bill, covering 13,300 acres in Kentucky, was signed into law. The other bills, specifying a total of 2,873,724 acres throughout Colorado, Utah, Nebraska, Michigan, Nevada, and the Great Smokey Mountains in North Carolina and Tennessee, were in various stages of the legislative process.

A number of bills of concern to the mining and minerals industry were introduced, including several pertaining to the National Defense Stockpile activities. They include removing the President's authority to establish goals and place administration responsibility with the U.S. Department of Defense, adding coke to the stockpile, establishing an agriculture barter program to acquire materials, and disposing of 10 million troy ounces of silver from the stockpile. All of the bills have been referred to the appropriate committees. The only change in the law occurred when amendments to prohibit the President from reducing stockpile goals below the goals in effect on October 1, 1984, at any time prior to October 1, 1986, were approved as part of the Defense Authorization bill in the House and the Supplemental Appropriations bill in the Senate for fiscal year 1985.

Six major pieces of legislation concerned with problems of the U.S. steel industry were considered during 1985. They included a bill to form a Government corporation to revitalize the industry, a bill to ban the importation of consultation steel products from the European Economic Community until new arrangements are negotiated, a bill to amend the Steel Import Stabilization Act, a bill to remedy violations of bilateral steel products trade agreements with the European Communities, and companion bills in the House and Senate to establish a breakpoint tariff system on imports of certain ferroalloys. Under an amendment to the National Bureau of Standards Authorization Act, which was approved by the President, $2.5 million was set aside for a Government and/or industry research project to develop new steelmaking technologies.

A section entitled "Negotiations and Action Regarding Agreements to Restrain Copper Production Voluntarily" was attached to a spending bill, House joint resolution 465, signed by the President. This provision, although not binding by the law, is meant to express the intent of Congress and directs the President through the U.S. Trade Representative to negotiate production restraints with major copper exporting countries. The President earlier vetoed the same copper provision when it was attached to a textile import restraint bill.

A wide variety of trade bills was introduced. Toward the end of the session, a bipartisan group of 33 Senators introduced Senate bill 1860, the Trade Enhancement Act of 1985, to amend the Trade Act of 1974 to eliminate barriers and distortions to trade, to provide authority for a new round of trade negotiations, and to promote U.S. exports. This bipartisan, comprehensive measure indicates that Congress may be moving away from the protection of specific industries in favor of broader changes in U.S. trade policy.

Two bills, both entitled "Federal Technology Transfer Act of 1985," were introduced concurrently in the House and Senate. Both bills establish a Federal Laboratory Consortium (FLC) to assist in the transfer of technology from labs to private businesses. In the House version, the FLC would be established within the National Science Foundation, and in the Senate version, it would be established within the National Bureau of Standards. The House bill also contains provisions concerning Government sharing of patent-license royalties with the inventors and standards that would effectively guide Federal employees to avoid conflicts of interest.

In November, members of the National Critical Minerals Council were sworn in. Priorities of the group, as mandated by Congress, include the first long-range assessment of national material needs and establishment of an advanced research and development plan. The Council must also advise the President on trends in minerals and materials matters that affect national and economic security. The group can recommend methods to increase exploration and development methods for critical minerals within the United States and the boundaries of the Exclusive Economic Zone.

The first public hearing of the Council was held in January 1986.

The long dormant issue of regulation of mining and minerals processing waste under the Resources Conservation and Recovery Act (RCRA) of 1976 became active as a result of legal action by a group of citizens against the Environmental Protection Agency (EPA). In response, EPA proceeded with regulation of copper dump leach solutions and mining waste and tailings from gold, lead, silver, and zinc mining. The agency also initiated the first phase of rulemaking for other mining wastes and submitted its "Report to Congress. Wastes From Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden From Uranium Mining and Oil Shale."[2] Following review, this report is to be the basis upon which EPA plans to make decisions regarding the regulation of mining waste under RCRA.

A proposed transfer of responsibility from the Bureau of Land Management (BLM) to the U.S. Forest Service for the underground minerals in 205 million acres of national forests was agreed upon by the two agencies. The Forest Service currently makes recommendations on the mineral lands and the BLM issues the leases. The two agencies have shared in the supervision of operations. The transfer would result in consolidating responsibilities for minerals and effect an estimated annual savings of between $27 million and $32 million.

Before adjournment, the House of Representatives passed major tax reform legislation. The bill changes provisions in the current tax law dealing with corporate tax rates, investment tax credit, capital gains treatment of minerals and timber producers, percentage depletion allowances, and the existing 25% credit for increases in research and development.

**Exploration.**—Mineral exploration activity in the United States continued to decline in 1985. Starting in 1981, the BLM has collected data on claims and annual filings of assessment work on Federal lands. A summation of these filings provides an estimate of the prospects the industry is currently exploring or examining. The BLM data show that from 1983 to 1985 new claims in the Western States have declined by 38% and assessment filings have declined by 22%, resulting in a total decrease of 24%. These figures confirm the drop in exploration activities. Again, low metal prices created by worldwide excess production were the cause of reduced metal exploration expenditures. This led to the consolidation of exploration operations and to staff reductions by several major companies. Gold and precious metals continued to be the major commodities sought domestically, with up to 90% of the exploration and development activities estimated to be for these metals in 1985.

New exploration methods and techniques continue to be developed despite the reduced exploration activity, as companies increase their efforts to identify suitable targets and develop them at a lower cost. For many years, satellite data have identified potential mineralized areas, but the use of satellites will probably increase in the future. New satellites will give resolutions down to 10 meters and generate far more information than earlier systems. These satellite pictures, combined with computer analysis, can save exploration companies vast sums of money. If prospecting for a mineral in a remote area, the first step is to purchase Landsat satellite data tapes of the area. The data can be fed into a computer together with comparative data for a known area of the mineral deposits.[3] The computer builds up a spectral picture (pattern vector of different infrared and ultraviolet wavelengths) for the mineral. Then working with a deduction process like natural selection, the program locates areas where there is more than an 85% likelihood of success. The program can find logical rules and assumptions that might never occur to the human prospector. Recently, a major mining company completed a survey of the spine of the Andes, covering 5,000 kilometers from southern Chile to Peru. After Landsat images identified promising areas, then geologists went in by helicopter to collect samples. This technique proved highly effective and is reported to have identified promising precious metals deposits.

The use of computers is spreading to all phases of exploration as hardware becomes more powerful, more portable, and less costly. During analysis and interpretation, the computer does much of the time-consuming, costly work such as drawing maps, computing statistics, and searching for anomalies. As an example, a gyrosystem linked to a computer for the accurate surveying of boreholes has been successfully used at a number of minesites in the Republic of South Africa.[4] The new system, made by Boart Drilling, accurately measures borehole inclinations and determines the precise locations of intersection points in the boreholes. Based on eight boreholes surveyed for clients, the company has found the system to be a vast improvement over conventional borehole surveying techniques, which use magnetic compass-inclinometers and miniature photographic systems. The system is not affected by magnetic fields emanating from the surrounding rocks, drill rods, or the electrical components of the instrument. Two accelerometers measure the inclination of the probe in the borehole. The system is lowered down the hole on a seven-core electric cable. All data are relayed through this cable to a Hewlett-Packard minicomputer housed in a logging truck on the surface. The use of the computer has significantly improved sampling intervals and has resulted in virtually instantaneous data processing. The computer is capable of plotting the shape of the borehole viewed in any direction, such as a plan view from above or a horizontal view. Typically, the gyroscope data are logged every 10 meters, compared with every 54 meters with conventional surveying systems. Even with this increase in logging data, the new system can obtain a complete printout of all survey details in about 60% of the time required to log a borehole using magnetic photographic methods.

**Development.**—The strategy of curtailing development during periods of low prices and expanding development during profitable periods has historically been a standard mining practice to deal with fluctuating metal demand and prices. With the chronic weakness of the market over the last 5 years, rather than relying on this strategy, companies have been forced to develop innovative techniques to reduce mine development costs. An excellent example is the change from the use of conventional drill and blast methods to roadheaders at the San Manuel Mine, Arizona. Beginning in 1980, the mine started reducing its work force in response to falling copper prices, and early in 1983, all drift development was curtailed.[5] However, by mid-1983, San Manuel management was faced with the need for drift development to meet future production goals and decided to begin a program by the end of the year. At the peak of its effort, San Manuel had approximately 100 workers working 3 shifts per day driving between 500 and 700 feet of drift per month. With the poor economic climate, a method of development was needed that was less labor intensive but could still achieve the rapid advance rates required.

After extensive research into new methods, roadheaders were selected because they can achieve rapid advance rates, and an advantage was also foreseen in reducing the number of working areas and eliminating congestion and conflict with mine production. After driving more than 3,500 feet of preextraction development headings on haulage and grizzly levels for ongoing support of block caving at the mine, roadheaders have cut drifting costs by 30% and increased the rate of advance by 37% when compared to conventional drill and blast methods. Such results were achieved in formations ranging from 19,000 to 30,000 pounds per square inch compressive strength, rock that is more or less typical of a low-grade porphyry copper. By midyear 1985, the San Manuel Mine had four roadheaders in operation. One roadheader is equipped with high-pressure, water-assisted cutting heads, utilizing water pressures of 9,000 pounds per square inch to assist machine performance. Although still experimental, high-pressure, water-assisted cutting should allow the roadheaders to successfully cut the hardest rock, to reduce destructive vibration in the machine, and to dramatically reduce dust.

Hydraulics has permitted automation of the drilling process on a much greater scale than with pneumatic drills, but the operator still plays a crucial part in drilling productivity. Differences in the handling of booms and drills have been found to cause variations in productivity levels by up to 30%. The operator also controls the accuracy of the profile and pull of the round. The spacing between holes, their pattern, and alignment are critical as any underbreak or overbreak results in an increase in costs. Computer technology to fully automate the drilling jumbo is now available, and several companies have entered the market.

Tamrock of Finland produced a computer-controlled jumbo, Datamatic, on which booms move in accordance with a drilling pattern preprogrammed into its memory.[6] The location, length, and direction of each hole are predetermined, and the jumbo automatically executes each hole in succession. A constant laser beam provides the reference from which all coordinates are calculated. This reference beam enables the computer to work out the drill's position and calculate the required boom joint angles for each successive hole. Therefore, hole alignment is very fast, because it does not depend upon the position or direction of the rig itself. Besides drilling according to the preprogrammed pattern, the Datamatic can also be operated with coordinated or direct control. With coordinated control, the driller positions the booms in the desired direction while the computer calculates the boom joint positions. If, as occasionally will happen, it is impossible to collar the hole in the predetermined position because, for example, it coincides with a rough promontory on the face from which the bit slips, the driller can manually move the boom to a new position and press a button. The computer will then automatically compensate for drill direction so that the hole terminates at the same predetermined point. A visual display unit also aids the operator by continuously showing boom alignments, penetration rates, and drilling patterns, including the holes that have been and are to be drilled. The operator thus has a visual check on the proceedings, permitting him or her to alter pressures, rotation rates, and drifter positions to maximize productivity.

Montabert, a French manufacturer, developed a fully computerized jumbo, Robofore, that automatically controls the various drilling functions in a drilling cycle.[7] After a 2-year test program, an operational machine has been installed in the Arbed iron mines in France. In addition to providing fully automatic drilling capability, the jumbo offers accurate special feed positioning to about 20°; hole collaring positioning to about 2.5 inches; a traveling speed from hole to hole of about 10 seconds, compared with 24 seconds during manual operation; smoother boom movements because speed is progressive; and improved drilling efficiency. The basic boom movements are recorded by means of sensors. These sensors direct the gathered data to a computer that controls the boom cylinders. Using the same microprocessors, other functions are also computerized, such as boom auxiliary movements (extension and feed anchoring), automated control of the drilling phase (feed advance and retraction), drifter regulation, control of safety parameters (oil level and temperature, etc.), as well as other safety devices to avoid boom interference. After having positioned the rig and the booms, the operator selects the required drilling pattern, which is fed into the computer. There is no other human intervention during the drilling cycle. The operator, however, can manually take over the entire drilling cycle or continue to drill on a semiautomatic basis. In the latter case, the boom is maneuvered and positioned automatically, but hole collaring is controlled by the operator. When drilling conditions require a change, new programming must be introduced into the computer.

The Tround Blast Hole Drilling System, a new hard-rock drill that can perform at rates ranging from two to four times faster than a conventional drill, was tested with the cooperation of a major oil company at a gas well in Arkansas in formations consisting of hard sandstone and shale.[8] The test results were viewed as positive. Based on a technology known as the Open Chamber System, the drill involves multiple projectile cartridges fed into and ejected from a novel arrangement of firing chambers. This arrangement, along with the complete elimination of the reciprocating breech element of conventional guns, makes possible extremely high rates of fire, if required. The drill utilizes multiple projectiles, which when fired in salvo, do not impact simultaneously, but produce delays measured in millionths of a second owing to slight variations of projectile weight and gas dynamics. Against rock, this rapid secession of impact generates shattering shock waves ahead of conventional drill bits.

**Underground Mining.**—Faced with a chronically depressed domestic mining economy, surviving operations have been forced to curtail their work force and improve productivity. In nearly all operations, this has involved major changes and the development of new methods and techniques. Inco Ltd. of Canada, a company that operated at a loss for the 3 years prior to 1984, is a typical example of the changing mode of operations that characterize today's mine management.[9] In a priority program to reduce costs, the company established a formal mine research department with a broad mandate to develop easier, safer, and more productive mining systems. The initial focus of this program was directed toward ground control, stoping methods, and equipment development. Basic ground control research and the application of rock mechanics to bulk stoping systems were determined by Inco to be essential tools in the development of efficient mining methods at greater depths. As a result, numerical modeling techniques are being used to design the mining geometry, sequence, and destressing program required to produce optimum ground conditions. Microseismic source location systems are also being evaluated for their potential in forecasting impending problems. A spray-on, fiberglass-reinforced epoxy resin is being developed with the expectation that it will reduce or eliminate rockbolt support. The epoxy would provide support similar to shotcrete at 10% of the shotcrete volume and 25% of the time required for rockbolt installation. There would also be a reduction of the material handling problems associated with shotcrete.

A major problem faced by Inco was the high cost of underground stoping methods. Historically, near surface, larger ore bodies have been mined with bulk methods such as blasthole and caving, while smaller, irregular ore bodies and ores at depth or in pillars have been recovered by selective methods such as cut-and-fill or undercut-and-fill. However, as larger ore bodies have been depleted and as mining has progressed to deeper levels, reliance on the small blast, high-cost mining methods increased. By 1981, only one-third of Inco's production was recovered by bulk methods, and despite the use of mechanized equipment, the productivity of the mines was decreasing at that time.

To reverse this trend, the vertical crater retreat (VCR) method was instituted. This combines the productivity advantages of bulk mining with the ground control advantages of selective fill methods. At Inco, the ore zone is divided into a series of panels that are silled at the top for down drilling and developed at the bottom for ore removal. A panel is drilled from top to bottom, and explosive charges are placed near the bottom of the holes. Each charge is fired separately. A horizontal slice 10 to 12 feet thick is removed with each shot. Only the swell is removed after the blast. Final cleanup of the panel is done by remote (radio) controlled loaders. The panel is then filled with consolidated backfill, and the excavation of adjacent panels proceeds in a sequential manner. The company reports that VCR mining has increased bulk-mined ore from 32% to 70% of the total tonnage.

Another part of the Inco program is to build prototype equipment that can be applied to a particular mining concept or need rather than adapting the mining to suit available equipment. Under this program, Inco has built a prototype in-hole drill that features (1) low mast height to reduce the size of openings required for machine operation, (2) hydraulic control of the drill string for greater accuracy, (3) positive breakout of the rods to eliminate the use of wrenches, (4) power to drill 9-inch-diameter holes up to 400 feet long, (5) motorized wheels for maneuverability, and (6) breakdown features so that the rig can pass a 24- by 24-inch opening. The company is now incorporating mechanized rod handling and microprocessor monitoring and control to provide full automation of the drill. When completed, one employee will be able to monitor two or more drills. A prototype continuous loader capable of producing five times the output of conventional load-haul-dump units has also been constructed. The unit has an oscillating lip that changes the angle of repose of the muckpile, thus providing a continuous flow of muck to a short chain conveyor. The application of microprocessor monitoring, sensing, and control is now being developed for this loader.

Concurrently with its research program, the company reopened an idle mine at the start of 1983 and designated part of the mine as a working model for higher productivity development. Named the Research Mine, it has been used to test such ideas as concentration of production faces, a multidisciplined work force, and financial incentives to improve productivity. To concentrate production in as few workplaces, levels, and stoping methods as possible, and to maximize the output from each place, the model at the Research Mine has been designed so that all production comes from three active stopes on one level, using a VCR method that leaves no pillars. Inco plans to mine a typical block within 3 years, compared with the 15 years historically required. Using this method, productivity improved and only 33 operating employees were required per shift. This created another problem; under the existing job classification system, the 33 employees required the skills of 26 job classifications. To address the problem, 6 new job classifications were created that included the skills of the 26 former classifications. According to the company, the reclassification has increased flexibility in movement of people from one job to another, and it has provided job enrichment and higher pay for employees while simplifying administration. Underground computer terminals are used for transmission of timekeeping, personnel records, production data, and supply ordering. The normal time for paperwork has been reduced by 80%.

The concept of incentive earnings, which historically has been provided only for people in production or development where output can be measured (tons per worker shift or feet advance), was also examined. The present system leaves about 60% of the employees in a supporting role with little sense of motivation or participation. A unique incentive system was devised to pay support crews as a function of the output of production crews. The system has improved the level of service for production crews and encourages cooperation among all work groups. The system also provides a financial benefit to support crews when their working number is reduced. According to the company, the changes generated from these operations at the Research Mine has made a significant impact on the productivity of the company's other mines. Inco's innovative approach and research effort must be considered successful in that the company was operating at a profit by the end of 1984 and throughout 1985.

Another example of the innovative nature of mining today is a new mining method for use in highly stressed ground subject to rock bursting. Under a three-way memorandum of agreement between the Hecla Mining Co., the University of Idaho, and the Bureau of Mines, an extensive rock mechanics investigation is being conducted at an experimental stope in Hecla's Lucky Friday Mine at Mullan, ID. Termed the Lucky Friday Underhand Longwall (LFUL), this experimental stope is a radical departure from traditional overhand cut-and-fill mining. Development in the 500-foot-long, mechanized underhand cut-and-fill stope is through a modified spiral-ramp system, located in the footwall. The ramp is being supported with innovative ground-control systems such as cable bolts and steel-fiber-reinforced shotcrete. Ore from the stope is trammed in 2-yard, front-end loaders down the ramp system to a 5-foot-diameter ore pass. The reinforced shotcrete is also used in the ore pass for both primary support and as a liner system. A rock mechanics investigation includes the development of in situ stress data using overcoring and measurement of rock response during mining using multipoint extensometers in the foot and hanging wall, surface closure points in the access ramp, and load cells placed within the high-density sandfill. Geological site characterization studies include fracture mapping and coring for physical property testing. A two-dimensional, finite-element model of the test area has been constructed and is being calibrated with mine measurements for use as a predictive mine design tool. If the test stope proves successful, the mining method will be used throughout the mine.

A new mining prop has been developed to withstand high loads and to yield gently as closure occurs in the highly stressed openings of deep South African gold mines.[10] The Bestoprop, a patented design, uses a specially shaped timber inside a convoluted thin-wall steel casing. The timber has longitudinal radial grooves cut into the sides, deep at one end and tapering to a shallow point at a predetermined position along the length. The wood fiber fills the space as the prop compresses. Small convolutions at the ends of the steel casing allow it to concertina as closure takes place. By using different timbers and by varying the lengths and widths of the grooves, different load bearing and yield capacity props can be constructed. It is therefore possible to design props for the loading conditions of individual mines.

The Bureau of Mines, in cooperation with mines in the Coeur d'Alene Mining District, has investigated the use of lightweight concrete to form continuous tunnel liners in deep mines in which ground support is difficult owing to high rock pressures. The lightweight concrete is made by mixing a special prefoamed agent directly into the concrete mix, thereby reducing the density of the concrete. Typical densities for lightweight concrete range from 25 to 100 pounds per cubic foot. Depending on the design application, a lightweight concrete can be developed with adequate strength and with energy absorbing characteristics that are essential in soft, caving, squeezing, and bursting ground conditions. Several successful field trials of the lightweight concrete liner have been made at cooperator mines. The first test section has been in place for 3 years, and there has been no evidence of structural distress since placement.

One test placement used an innovative airbag formwork that can greatly reduce forming costs in underground mines. The formwork is shaped with dumbbell ends that function as self-sealing bulkheads. Also, a section of a spiral access ramp was lined with shotcrete containing steel fibers and silica fume. This became the primary ground support, replacing rock bolts and mesh. The test was a significant development because the rising cost of rock bolts has now made mine operators look for alternative, less costly ground control technologies. The same material was used to line an adjoining 200-foot-long raise-bored ore pass. Silica fume is a cement additive obtained from the manufacture of silicon metal. It appears to significantly increase the strength of shotcrete and allows the shotcrete to be built up several inches in thickness in a single application with reduced rebound.

The first practical electric truck system for underground mines has been developed in Sweden.[11] Powered through an overhead trolley line system, the truck has now completed more than 2,500 miles of underground operation in the Kiruna Mine. Each motor of the four-wheel-drive truck powers a pair of wheels. The motors have a continuous rating of 308 horsepower each, but for noncontinuous use, which is typical of mining operations, considerably higher levels can be generated, providing more power for high-speed haulage up steep ramps. The new truck has none of the ventilation problems, fumes, and heat associated with diesel trucks. It has a load capacity of 55 tons and easily achieves speeds of up to 16 miles per hour on 12% inclines. On level ground, it runs at up to 32 miles per hour and accelerates from zero to 25 miles per hour in 4 seconds unloaded or in 8 seconds loaded. Mechanical switches or turnouts are not used on the trolley line. At junctions or crossover points, the pickup arm is lowered and the truck proceeds under battery power for several feet until it is in the branch under the trolley line where the pickup arm is again raised. The truck also operates under battery power when it meets another truck on the line and at the ends of the line when the truck proceeds to the loading or dumping point. To engage the trolley line, the operator steers the truck under the approximate center of the line, presses a button, and the computer takes over. With the aid of sensors on the pickup arm, the contacts are precisely located and the system locked into position. More than 30,000 automatic connections and disconnections made during the mine trials have shown that truck speed during connection can be up to 9 miles per hour, and disconnection is possible at any speed. The trolley arm allows the truck to deviate more than 6 feet from the center line.

Operating costs of the electric truck are reported to be only 50% to 60% of similar size diesel trucks. In addition, maintenance costs are lower owing to the all-electric traction system and lower tire costs. Microprocessor-controlled speed regulation eliminates wheel spin and no tire wear has been noted on the prototype truck. The microprocessor also regulates and controls all vital electrical functions. The first series of electric trucks is expected to be on the market in 1986.

Four spray coolers were designed and built as part of a Bureau of Mines program to investigate direct-contact (warm air to cool water) spray cooling systems.[12] A single-stage cooling unit was tested in a New Mexico uranium mine, and a two-stage cooler and a three-stage cooler were tested in a South Dakota gold mine. During these in-mine tests, the two-stage cooler reduced 16,387 cubic feet per minute of 76.8° F wet bulb air to 69.3° F wet bulb using 55 gallons per minute of 50° F water. This represents a cooling power of 39 refrigeration tons. A three-stage unit cooled 26,200 cubic feet per minute of 80.1° F wet bulb air to 73.5° F wet bulb using 50 gallons per minute of 48.7° F water, demonstrating a cooling power of 59 refrigeration tons. The spray chamber cooling performance is considered excellent. In-service maintenance requirements have been minimal thus far. The units continue to undergo long-term evaluation.

**Surface Mining.**—Several surface mines were shut down in 1985 and others curtailed production. As in underground mining, the companies were forced to innovate and reduce costs to remain in operation. A good example is the $400 million, 3-year modernization plan announced for the Bingham Canyon copper mine, which suspended operations in March 1985.[13] The company plans to install a large portable, in-pit crusher that will feed a 5-mile belt conveyor system from the mine to a new grinding facility. The belt system will convey the ore from the lower levels of the pit through an existing railroad tunnel to the grinding plant. The new plant will house three grinding lines, each consisting of a grinding mill and two ball mills. Ore slurry will be transported from the flotation portions of the two existing concentrators through two 13-mile-long slurry pipelines. Existing facilities that will be eliminated by the project include the rail ore haulage system between the mine and concentrators, the Bonneville concentrator, and the crushing and grinding units at both the Magna and Arthur concentrators. The modernization is planned for completion in late 1988. Production capacity will be reduced 25% compared with production before closure, but the amount of refined copper produced will drop only 10%. This is due to improved processing efficiency. Optimally, the new installation could bring about a reduction in production costs of $0.20 per pound according to the company.

The use of computers in open pit mines continues to expand. More and better software is being developed to aid the miner in every aspect of operations. Optimum drilling locations and sophisticated borehole grade and tonnage programs are used for exploration and reserve analysis. Geomechanical data are input to design the mines and pit slopes and to determine ground pressure limits. Computers plan the production sequence designing optimal bench layout and haulage rock placement, often for years in advance. Blasthole designs are determined, and simulation programs are available to assess the effect of blasting and blasthole patterns. However, the use of microprocessor technology for onboard operation of equipment is the emerging new development, and the merging of electronic and mechanical technologies in heavy equipment continues to accelerate. Severe conditions, such as vibration, extreme temperature, dust, moisture, and physical shock, are rapidly being overcome, and mining equipment is becoming covered with sensors that feed information to microprocessors, which in turn make rapidly calculated decisions to optimize the operation of the equipment.

The Caterpillar Tractor Co. announced a new impact ripper that significantly advances ripping technology.[14] A hydraulic impactor transmits additional forces to the tip of a specially designed shank, adding force to the power normally delivered during conventional ripping by drawbar pull. The operation of the impact ripper is fully automatic and does not commence until the tip comes in contact with high-strength material. When the ripper tip passes back into low-strength material, the impactor automatically shuts down. The ripper can also be used for secondary breakage by positioning the ripper tip over a bolter and activating the impactor manually. Company tests compared a D9L tractor dozer equipped with an impact ripper with one fitted with a parallelogram ripper. The testing ground was cemented limestone with a seismic velocity of 11,000 feet per second. The results showed that the impact ripper produced 560 tons per hour, while the conventional parallelogram unit ripped 155 tons per hour. This represents a production increase of about 350%. The tests also demonstrated that there is a cost savings using the new impact ripper. The standard ripper costs were about $0.41 per ton, compared with $0.13 per ton with the impact ripper. Cost for blasting was $0.19 per ton.

Futher development of mobile crushers continued, and a trend is beginning toward the use of high angle conveying systems. These provide a lower cost alternative to transporting materials out of a pit with trucks. Continental Conveyor and Equipment Co. Inc., which installed the first commercial high angle conveyor at a western U.S. coal mine, is constructing a high angle conveyor for Majdanpek Copper in Yugoslavia. The conveyor will be 6.5 feet wide and have a lift of 304 feet and is designed to carry minus 10-inch copper ore with a density of 1.6 tons per cubic yard at a rate of 4,000 tons per hour up a 35.5° incline. The design uses a sandwich belt principle and will permit installation of a second conveyor to elevate ore from a deeper pit location and transfer it onto the tail of the first unit. Operation is scheduled to start in 1987. Goodyear Rubber Products Co. has developed a wraparound conveyor belt that can convey material up a 30° slope with potential speeds of 800 feet per minute. The folding conveyor belt, which encloses the material from loading to unloading, is made with specially constructed hinges fastened to the cover flaps at each edge. The flaps allow the sides of the conveyor to cover the material. A prototype belt has been installed in a fine coal processing unit in Ohio. The Australian Mineral Industries Research Association is investigating the potential to develop a high angle conveyor that does not rely on framework to support the conveyor. The proposed concept, which could be extended to open pit operations, is based on the recent successful installation of a Flexowall belt in Belgium. This conveyor raises 3,000 tons per hour of coal over a vertical lift of 40 feet as a freely hanging catenary without a supporting frame. Such a design would cost much less than present designs and would also be very mobile.

The world's two largest tractor dozers were both introduced in 1985.[15] Both incorporate new design features and claim superior performance with reduced fuel consumption. Komatsu Ltd.'s D475A is a 91-ton dozer capable of producing engine output of

740 horsepower. The combination of the new high-output engine and lockup torque converter is reported to increase workload by 40% and decrease operating costs by up to 30% compared with earlier models. The D475A has a capacity of 30 cubic yards with a straight blade, and 37 cubic yards with a universal blade. It can also be equipped with a single or multishank variable-type ripper. The physical ripping limit is rock with a seismic velocity of 9,800 feet per second and maximum ripping depth with a single shank of 5.5 feet.

Caterpillar Tractor's D11N is a 93-ton dozer capable of producing engine output of 770 horsepower. The D11N is 5% heavier than the D10, and a new engine provides 10% more power. The increased power and weight is reported to improve the new dozer's productivity by 10% to 15% over that of the D10. Blades have been redesigned with a more open profile and greater heel clearance. Capacity with the universal blade is 40 cubic yards. The standard shank ripper arrangement is 8 inches shorter than that of the D10. A shorter shank provides room for a deep arrangement with a longer shank offering the user more versatility. Maximum penetration with a deep ripping arrangement is 7 feet.

**Remote Mining.**—Low-grade ore combined with high processing costs prevent many deposits from being mined by conventional methods, but the development of solution mining continues to emerge as an alternative method for mining of such metals as copper, gold, silver, and uranium. The Bureau of Mines continued active research on in situ leaching and published several reports. One report describes the development and application of a computer program, PHASEQ/FLOW, for simulating the geochemistry of leaching.[16] The geomechanical flow simulator is capable of describing the dynamic changes in chemical composition of an aqueous solution during flow through a permeable medium. The report describes several applications: generic batch equilibria, flowing equilibria, uranium roll-front deposition, and roll-front leaching. Another report describes a mine test of the new potassium chloride-potassium carbonate two-stage in situ uranium leach process carried out at the Intercontinental Energy Corp. Zamzow project site in south Texas.[17] Substantial quantities of high concentration uranium were produced, indicating the feasibility of the leach solution. The test results yield information regarding the reservoir dispersivity, the average cation-exchange capacity of the formation, and the distribution coefficients describing cation-exchange reactions. The test results also demonstrate the existence of permeability anisotropy and of disturbed flow fields.

The Bureau of Mines has conducted research to improve technology for recovering precious metals from low-grade resources, and results were published.[18] Many of the reported findings are recent, and some of the work described is ongoing. Topics discussed include cyanidation of carbonaceous gold ores to enhance gold recovery, a new method for precipitating mercury during cyanide leaching of gold ores, a staged heap leaching process to generate suitable solutions for direct electrowinning of gold, use of anion-exchange resins to recover gold from cyanide solutions, and precious metals recovery from electronic scrap.

A midget submarine able to rest on the sea floor at a depth of 1,500 to 2,000 feet will shortly be available for seabed exploration and geological investigations.[19] It is 90 feet long and has two chambers. One chamber, where all machinery and navigational equipment are located, houses a crew of seven with six divers. The other is filled with helium-oxygen atmosphere compressed to the operating depth of the submarine. The vessel, where the divers can stay in saturation for a month or more, was built for either maintenance, repair, or installation of oil well heads or mineral exploration of the seabed. It can operate without repeated reference to a surface vessel in all weather and up to 150 miles from shore. The submarine will eventually be equipped with a nuclear reactor that will enhance the ship's range and enable it to operate under the Arctic ice. With the nuclear propulsion unit, the submarine's length will increase to 117 feet and its range to 300 miles.

The Bureau of Mines also evaluated the extent of recoverable phosphate resources in the Southeastern Coastal Plain of the United States by the experimental borehole mining method.[20] Phosphate resources at overburden depths greater than 100 feet are, as a rule, currently unsuitable for recovery through conventional mining methods because of economic, environmental, or technical considerations. In the identified deposit areas, borehole mining operations are projected to yield a more favorable rate of return and to be environmentally more desirable than conventional surface mining. The resources have been classified as hypothetical and speculative and are subject to updating as additional exploratory data become available. Hypothetical and speculative phosphate resources with a minimum in situ grade of 5% $P_2O_5$ amenable to borehole mining are estimated to total about 425 billion tons. With projected borehole mining capabilities and current conventional beneficiation procedures, this resource would make available approximately 70 billion tons of phosphate rock product at an estimated grade of 30% $P_2O_5$.

**Beneficiation.**—New technology and cost-reducing techniques were also the dominant factor in the processing of ores throughout the industry. Some notable advances were made in the crushing of materials. Rexnord announced a new cone crusher designed to fit an existing 7-foot crusher foundation with minimum modifications that provides twice the production capacity of the existing 7-foot cone.[21] A prototype, which features a head diameter of 90 inches and a scaled-up power rating of 1,000 horsepower, is being tested at Bougainville Copper Ltd.'s Panguna concentrator. According to the manufacturer, the following design features have increased the volumetric limit of the crusher compared with units of comparable size. The head diameter is approximately 10% larger, increasing volumetric capacity by the square of the diameter or 15% to 20%; head throw is 40% greater, increasing volumetric capacity by an equivalent amount; the larger diameter of the cavity feed zone also has increased volumetric capacity by 20% to 25%; and the elimination of the feed distributor has reduced the restriction of feed material flow and resulted in a 15% to 20% increase in capacity. In addition, the machine has a hydraulic tramp release system to provide a larger release stroke capability that remains the same throughout the liner wear life and a single head design that fits all crushing cavities.

The world's largest feeder breaker with a throughput capacity of 300 short tons per hour was constructed by W. R. Stamler Corp. for use in overburden and frozen tar sand at Syncrude operations in Canada.[22] The 250-short-ton feeder breaker is 27 feet long by 30 feet wide by 28 feet tall. The hopper capacity is approximately 110 tons, with an intake height of 15 feet. The unit can be fed by 12-cubic-yard front-end loaders or rear dump trucks. The feeder breaker also incorporates a special 40-foot-long by 7-foot-wide boom conveyor, constructed to Syncrude's specifications. The feeder-breaker channels broken material onto the boom conveyor, which can be raised or lowered to feed onto collecting conveyors, as well as directly into haulage equipment. Heater plates, built into the hopper walls, prevent frozen tar sand from sticking to the sides of the hopper.

Superconducting magnetic separators are becoming commercially available. Their use would be applicable to ores where magnetic fields of high intensity are required to separate the components of solid mixtures containing weakly magnetic particles. In a conventional electromagnet consisting of a copper coil and an iron yoke field, intensity is limited to about 2 tesla owing to the saturation magnetization of the iron. The technology of superconductive magnets helps overcome this limit. During operation, the magnetic system is kept at temperatures close to absolute zero by using liquefied helium. The coils of the electromagnet consist of superconducting wire made of special alloys, which, at a temperature of about -270° C, has no electrical resistance. Therefore, these alloys permit current densities 50 to 100 times higher than standard copper wire.

A superconducting magnetic separator was constructed for a kaolin clay processing plant in Georgia by Eriez Magnetics.[23] With a magnetic field strength of 2 tesla, the machine is expected to remove particles of ferritic impurities ranging down to micrometer size, thus producing a brighter, purer clay product. The new separator, measuring 13 feet by 13 feet by 7 feet and weighing 230 short tons, occupies 34% less space and weighs 47% less than conventional separators of the same strength, thus reducing plant floor space requirements as well as foundation and installation costs. Compared with similarly sized, conventional separators, electrical consumption by the new device will be 80% to 90% less, translating into annual savings of $150,000. The company is also operating a new 5-tesla laboratory model to test customer samples and obtain data for scaling up to commercial operations.

Another magnetic drum separator has been developed by KHD Humboldt Wedog AG.[24] The separator, named "Descos," is designed for both dry and wet high intensity magnetic separation, and the company has successfully tested a prototype of operational size. Bauxite and andalusite have been tested in continuous operation (dry process) with relatively high throughput capacity of up to 100 tons per hour. In processing bauxite from Brazil, the $Fe_2O_3$ content in a washed and in a calcined state can be sufficiently reduced so that the product meets specifications for the world refractory material industry market. In the prototype, the magnetic flux density outside the drum exceeds 3 tesla. Later models will have field intensities up to 5 tesla. The drum of the actual separator has a diameter of 4.8 feet and a length of 5 feet. The consumption of electric power and cooling water correspond to those of conventional, wet high intensity magnetic separators with considerably lower field intensity. The complete plant is skid mounted and may therefore also be used in existing preparation plants for pilot and field tests.

In general, gravity separation processes are inefficient when used on ores with five liberation sizes. A new type of mineral jig, which will gravitationally concentrate heavy minerals in particle sizes considerably finer than is currently possible, has been developed by Gev Logics Pty. Ltd.[25] The jig employs high centrifugal forces to concentrate the particles. Although still under development, the centrifugal jig is reported to have worked very well in a large number of tests with reported recovery of particles down to 20 micrometers and with a specific gravity differential of 1 to 1.5. Tests on tailings from a gold amalgamation and tabling operation recovered 60% of the gold rejected by the table, achieving a concentrate grade of 120 grams per ton of gold from a jig feed grade of 1.7 grams per ton. A new prototype is currently under construction that has been designed for higher centrifugal forces to allow effective concentration and recovery performance to be extended down to 10-micrometer particles.

Flash flotation cells developed by Outokumpu Oy and installed in Finnish concentrators have resulted in a dramatic increase in recovery.[26] They are used in classification circuits to process cyclone underflow and produce a final concentrate of coarse minerals that would otherwise be returned as circulating load to the grinding mill. Operating experience at the Hammaslahti concentrator has shown that the gold content of copper concentrate increased from 3.5 grams per ton to 4.4 grams per ton. In addition, copper recovery has increased about three percentage points when treating high-grade ores, with 30% to 50% of the copper recovery occurring during flash flotation. After vacuum filtration, the final moisture content of the concentrate was reduced by 1 to 2 percentage points, and the required cell volume for conventional flotation was reduced by 50%. The reduced cell volume cut energy requirements by 8,668 British thermal units per hour per ton of ore. Based on the results of the prototype cells at Hammaslahti, a commercial machine "Skim-air" is being marketed. Operations in Finland include the recovery of copper from magnetic iron ore tailings, use in a nickel-copper concentrator at Kotalahti, the Vuonos copper-cobalt concentrator, and flotation of copper from slag. Several other cells are being considered for use in the United States and Canada in gold and copper applications.

A flotation plant using a process developed by the Bureau of Mines was installed at a phosphate mine in Conda, ID.[27] The Bureau's process uses fluosilicic acid to depress the phosphate minerals while the carbonates are floated with a fatty acid emulsion. The carbonate float is followed immediately by a silica float with amine acetate. In 0.5-ton-per-hour pilot tests at the Conda mill, reconstituted feed material was deslimed before flotation. Reducing the desliming size made an additional 16% of phosphate available for recovery in the flotation circuit. Phosphate recoveries totaled 80% to 90%. A technique was also devised by the Bureau of Mines to recover coarse (plus 1,200-micrometer) North Carolina phosphate now discarded as waste.[28] Concentration utilizes the difference in particle sphericity between the relatively flat calcite and the rounded phosphate pebbles. Sizing, treatment in a continuous hydraulic classification system, and grinding upgraded a 17.0% $P_2O_5$ reject to 24.5% $P_2O_5$ with a phosphate recovery of 63%.

Instrumentation and control technology for mineral processing continues to produce substantial operating improvements. A report describing research on an advanced model-based control for semiautogenous grinding was released by the Bureau of Mines. This research was performed under Bureau of Mines contract by the University of Utah.[29] The report describes the derivation and verification of a simplified flotation model and discusses the implementation of a Kalman filter for estimating the values of unmeasured variables for input to controllers. It also describes several control strategies using the model-based approach. The strategies emphasize the nonlinear nature of the flotation plant. The report also discusses expected future trends in the implementation of such model-based flotation control strategies.

Another example of improving technology is a new mass flowmeter that combines a unique twin-loop sensor design with a smart digital transmitter to measure mass flow directly.[30] It is reported to have a high sensitivity to mass while remaining independent of other variables such as density, viscosity, temperature, and fluid inhomogeneity. The microprocessor-based transmitter preserves the high degree of accuracy available from the sensor and eliminates the instabilities characteristic of analog circuitry. During operation, the fluid enters the flowmeter and splits into two looped tubes that carry the fluid in a helical path. A driver causes the tubes to vibrate like a tuning fork. Sensors mounted on the flow-sensing tubes measure the deflections that occur owing to the Coriolis force. Because this effect is directly dependent upon mass flow rate, calculations, which are performed reliably and repeatedly by the microprocessor-based transmitter, yield accurate mass flow rate readings. These readings are presented in analog, frequency, and digital formats.

A northern Minnesota taconite company reports that the use of large complex polyurethane castings are reducing downtime and maintenance costs in iron ore processing.[31] Cast polyurethane discharge cones, pan liners, and trommel screens weighing up to 1,500 pounds each are said to last two to three times as long as rubber and metal components in handling hard, abrasive taconite ores. The largest, most complex of the parts developed by Irathane Systems Inc. are the discharge cones. In service for nearly 2 years in this taconite plant's 400-ton-per-hour, 36-foot-diameter autogenous mill, they are expected to last at least 6 years, twice as long as the cast iron cones previously used. Because the cast polyurethane parts can be patched with polyurethane-based trowelling compound, service life could exceed the 6 years anticipated. These wedge-shaped components measure about 6 feet high by 3 feet deep with a maximum width of 5 feet. At 1 taconite company, 9 such cones replaced 18 smaller cast iron cones and the installation took only one-half as long as for the metal units. Six years ago, a severe wear problem with trommel screens was also solved with the use of polyurethane. Steel-reinforced natural rubber screens were wearing out every 90 days; the current polyurethane screens are reported to last up to 300 days.

With the current interest in precious metals, a market for portable gold recovery equipment appears to have emerged. Vardax Consultants Inc. has reportedly sold six fine gold recovery plants.[32] The portable units are totally self-contained and engineered specifically to recover micrometer-sized precious metals. They are modular and can be built for production levels from 30 cubic yards per hour up to 500 cubic yards per hour. The raw material is completely scrubbed in a grizzly feeder and then put through a gravity concentrator. The 1/4-inch-size screened material goes through a series of accelerator concentrators to recover the fine and floating gold. A secondary system separates visual gold from black sands concentrate. Davage Technology Inc., the operator of a gold recovery system recently developed by the Battelle Memorial Institute, is making a mobile version of the system.[33] The 10-ton-per-hour unit, much smaller than the Vardax plant, is contained in a semitrailer with its own powerplant. It operates automatically on either dry material or slurry. It requires 50 gallons of water that can be recirculated. The five-step process uses no chemicals. The system has operated successfully during three 30-day runs on placers in Arizona and Nevada, recovering more than 95% of the gold present.

Another system that uses modular tanks to leach gold ores has been developed by Hitec Ore Processing Inc.[34] Any type of gold-bearing ore can be treated with tickle agitation or flood leaching, depending on the ore type. Leaching time is quite rapid compared with heap leaching. Tanks are charged, leached, flushed, and discharged in 9 hours. Gold recoveries are reported to be between 80% to 90% with low capital and operating costs. Typical operating costs for a 2,000-ton-per-day plant, using a 2.8-gram-per-ton ore, should be about $3.50 per gram. Capital costs for such an operation would be about $2 million. Savings come from the lower material handling costs, compared with heap leaching and conventional methods. Tundra gold mine near Talon, NV, will be the first site where tank leaching is used.

**Health and Safety.**—Preliminary injury statistics compiled by the Mine Safety and Health Administration show that fatalities in 1985 were the lowest in history with 56 miners killed in metal and industrial minerals mines. Although employment has dropped, the fatality rates are still very low, matching the previous low set in 1983. A new record low was also set for injury rates in 1985 at 4.26 per 200,000 employee-hours.

Two reports were released by the Bureau of Mines on ground-penetrating radar (GPR) systems to detect hazards. The first is on a system that is capable of penetrating 10 feet into the mine roof to identify anomalistic conditions.[35] It consists of a transmitter with carrier frequencies of 250, 500, and 1,000 megahertz, utilizing a dipole antenna and a receiver. A computer was used for data acquisition and data processing. Data analysis by computer enhancement revealed recognizable return radar signatures from the middle main roof of the test site. These stratigraphic anomalies can be cataloged for recognizable features, which from the past history of the mine, may have been shown to create strata control problems. The second Bureau of Mines report describes testing of a GPR system in the central Florida phosphate district to determine the feasibility of utilizing GPR technology for subsurface cavity detection.[36] The test area is situated in karst topography where sinkhole development is prevalent. State regulations require subsurface drilling of dam sites to identify underground anomalies; however, this method is not totally accurate in locating the subsurface cavities that could develop into sinkholes. The GPR system that was devised successfully penetrated over 50 feet of overburden and gave recognizable radar return signals characteristic of a rock-cavity interface.

Fires in underground metal and industrial mineral mines are one of the most life-threatening hazards faced by the workers. Contaminated air is the primary killer, and the most reliable defense against the spread of contaminated air throughout the mine is early fire detection and warning systems so that rapid evacuation of the workers can occur. Bureau of Mines research led to the design, prototype fabrication, and successful testing of an improved stench fire-warning system.[37] Stench systems are the most widely used means of warning miners in underground noncoal mines of fires or other emergencies. A stench system alerts miners that an emergency condition exists by injecting an odorant into the mine air. Although stench warning systems have been used successfully for over 60 years, present systems suffer several serious shortcomings, including odorant toxicity, unreliability of warnings, widely varying stench concentrations, and others. The new system overcomes the deficiencies of existing systems by substituting tetrahydrothiophene for the commonly used ethyl mercaptan stench odorant, and by using a specially designed stench injector. The improved injector reliably meters stench fluid into either ventilation-air or compressed-air streams at a precisely controlled rate. The Bureau has also designed and operated four other prototype warning systems for underground noncoal mines that are presently undergoing prolonged in-mine testing.[38]

Firefighting has made considerable progress in recent years owing primarily to the use of inert gases. In French underground mines, the use of nitrogen has changed the methods used to fight open fires.[39] With large quantities of nitrogen available onsite, it is possible to reduce the intensity of a fire and to extinguish it in a relatively short time. In a few hours or a few days after the use of the gas, it is possible for miners to come back to safe conditions in the workings. For this reason, all French coal mines are now equipped for the rapid use of nitrogen. Portable nitrogen generators are on-site, and contracts have been made with liquid nitrogen suppliers that guarantee delivery in short periods of time.

### Table 1.—Material handled at surface and underground mines in the United States, by type

(Million short tons)

| Type and year | Surface | | | Underground | | | All mines[1] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Crude ore | Waste | Total[1] | Crude ore | Waste | Total[1] | Crude ore | Waste | Total |
| **Metals:** | | | | | | | | | |
| 1980 | 520 | 1,180 | 1,700 | 77 | 11 | 88 | 597 | 1,190 | 1,790 |
| 1981 | 592 | 1,050 | 1,650 | 82 | 15 | 97 | 674 | 1,070 | 1,740 |
| 1982 | 371 | 677 | 1,050 | 60 | 12 | 72 | 431 | 689 | 1,120 |
| 1983 | 380 | 557 | 938 | 47 | 6 | 53 | 427 | 564 | 991 |
| 1984 | 420 | 614 | 1,030 | 57 | 10 | 67 | 476 | 624 | 1,100 |
| **Industrial minerals:** | | | | | | | | | |
| 1980 | 2,060 | 620 | 2,680 | 78 | ([2]) | 78 | 2,140 | 620 | 2,760 |
| 1981[3] | 1,150 | 584 | 1,740 | 68 | 6 | 74 | 1,220 | 590 | 1,820 |
| 1982[4] | 837 | 366 | 1,200 | 61 | 2 | 63 | 899 | 368 | 1,270 |
| 1983[3] | 1,070 | 155 | 1,230 | 62 | 1 | 62 | 1,130 | 155 | 1,290 |
| 1984[4] | 1,060 | 286 | 1,340 | 40 | 1 | 41 | 1,100 | 287 | 1,390 |
| **Total metals and industrial minerals:**[1] | | | | | | | | | |
| 1980 | 2,580 | 1,800 | 4,380 | 155 | 11 | 167 | 2,730 | 1,810 | 4,540 |
| 1981 | 1,750 | 1,640 | 3,390 | 151 | 20 | 171 | 1,900 | 1,660 | 3,560 |
| 1982 | 1,210 | 1,040 | 2,250 | 121 | 14 | 135 | 1,330 | 1,060 | 2,390 |
| 1983 | 1,450 | 712 | 2,160 | 109 | 7 | 116 | 1,560 | 719 | 2,280 |
| 1984 | 1,480 | 901 | 2,380 | 97 | 11 | 108 | 1,570 | 912 | 2,490 |

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 1/2 unit.

[3] Includes industrial sand and gravel. Construction sand and gravel data were not available for 1981 and 1983 because of biennial canvassing.

[4] Crushed and broken and dimension stone data were not available for 1982 and 1984 because of biennial canvassing.

### Table 2.—Material handled at surface and underground mines[1] in the United States in 1984, by commodity

(Thousand short tons)

| Commodity | Surface | | | Underground | | | All mines[2] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Crude ore | Waste | Total[2] | Crude ore | Waste | Total[2] | Crude ore | Waste | Total |
| **METALS** | | | | | | | | | |
| Bauxite | 1,130 | W | 1,130 | -- | -- | -- | 1,130 | W | 1,130 |
| Copper | 171,000 | 312,000 | 483,000 | 22,200 | W | 22,200 | 193,000 | 312,000 | 505,000 |
| Gold: | | | | | | | | | |
| Lode | 37,600 | 114,000 | 152,000 | 2,950 | 502 | 3,450 | 40,500 | 115,000 | 155,000 |
| Placer | 8,520 | 288 | 8,810 | 23 | 188 | 211 | 8,540 | 476 | 9,020 |
| Iron ore | 176,000 | 84,300 | 260,000 | W | W | W | 176,000 | 84,300 | 260,000 |
| Lead | W | W | W | 5,550 | 1,140 | 6,690 | 5,550 | 1,140 | 6,690 |
| Silver | 3,070 | 15,900 | 19,000 | 4,800 | 526 | 5,320 | 7,870 | 16,500 | 24,300 |
| Titanium (ilmenite) | W | W | W | -- | -- | -- | W | W | W |
| Tungsten | 2 | W | 2 | 273 | W | 273 | 275 | W | 275 |
| Uranium | 1,800 | 24,600 | 26,400 | 984 | 330 | 1,310 | 2,780 | 24,900 | 27,700 |
| Zinc | -- | -- | -- | 5,790 | 970 | 6,760 | 5,790 | 970 | 6,760 |
| Other[3] | 20,500 | 63,000 | 83,400 | 14,100 | 6,440 | 20,600 | 34,600 | 69,400 | 104,000 |
| Total metals[2] | 420,000 | 614,000 | 1,030,000 | 56,700 | 10,100 | 66,800 | 476,000 | 624,000 | 1,100,000 |
| **INDUSTRIAL MINERALS** | | | | | | | | | |
| Abrasives[4] | 225 | W | 225 | W | -- | W | 225 | W | 225 |
| Asbestos | 1,770 | 4,440 | 6,170 | -- | -- | -- | 1,770 | 4,400 | 6,170 |
| Barite | 1,050 | 604 | 1,650 | -- | -- | -- | 1,050 | 604 | 1,650 |
| Clays | 44,200 | [e]38,400 | 82,600 | 331 | [e]5 | 336 | 44,600 | [e]38,400 | 83,000 |
| Diatomite | 1,450 | 5,340 | 6,790 | -- | -- | -- | 1,450 | 5,340 | 6,790 |
| Feldspar | 2,600 | 1,270 | 3,870 | -- | -- | -- | 2,600 | 1,270 | 3,870 |
| Fluorspar | W | W | W | 141 | W | 141 | 141 | W | 141 |
| Gypsum | 14,100 | -- | 14,100 | 2,580 | -- | 2,580 | 16,700 | -- | 16,700 |
| Mica (scrap) | 1,040 | 685 | 1,720 | -- | -- | -- | 1,040 | 685 | 1,720 |
| Perlite | 648 | W | 648 | W | -- | W | 648 | W | 648 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Phosphate rock | 182,000 | 229,000 | 411,000 | W | -- | W | 182,000 | 229,000 | 411,000 |
| Potassium salts | -- | -- | -- | 15,600 | W | 15,600 | 15,600 | W | 15,600 |
| Pumice[5] | 560 | 28 | 589 | -- | -- | -- | 589 | 28 | 589 |
| Salt | 967 | W | 967 | 14,100 | W | 14,100 | 15,100 | W | 15,100 |
| Sand and gravel | 804,000 | -- | 804,000 | -- | -- | -- | 804,000 | -- | 804,000 |
| Sodium carbonate (natural) | -- | -- | -- | 6,730 | -- | 6,730 | 6,730 | -- | 6,730 |
| Talc, soapstone, pyrophyllite | 1,010 | 5,420 | 6,450 | 118 | W | 118 | 1,130 | 5,430 | 6,560 |
| Other[6] | 2,760 | 787 | 3,550 | 563 | 861 | 1,420 | 3,320 | 1,650 | 4,970 |
| Total industrial minerals[2] | 1,060,000 | 286,000 | 1,340,000 | 40,100 | 866 | 41,000 | 1,100,000 | 287,000 | 1,390,000 |
| Grand total[2] | 1,490,000 | 901,000 | 2,380,000 | 96,800 | 11,000 | 108,000 | 1,570,000 | 912,000 | 2,490,000 |

[e] Estimated. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Excludes material from wells, ponds, or pumping operations.

[2] Data may not add to totals shown because of independent rounding.

[3] Includes antimony, beryllium, manganiferous ore, mercury, molybdenum, nickel, platinum, rare-earth metals, tin, and metal items indicated by symbol W.

[4] Includes abrasive stone, emery, garnet, millstones, and tripoli.

[5] Excludes volcanic cinder and scoria.

[6] Includes aplite, boron minerals, graphite, greensand marl, iron oxide pigments (crude), kyanite, magnesite, millstones, olivine, vermiculite, wollastonite, and industrial mineral items indicated by symbol W.

Table 3.—Material handled at surface and underground mines[1] (including sand and gravel and stone) in the United States in 1984, by State

(Thousand short tons)

| State | Surface | | | Underground | | | All mines[2] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Crude ore | Waste | Total[2] | Crude ore | Waste | Total[2] | Crude ore | Waste | Total |
| Alabama | 13,100 | 1,710 | 14,800 | -- | -- | -- | 13,100 | 1,710 | 14,800 |
| Alaska | 34,200 | 417 | 34,600 | -- | W | W | 34,200 | 417 | 34,600 |
| Arizona | 152,000 | 153,000 | 305,000 | 20,400 | 196 | 20,600 | 173,000 | 153,000 | 326,000 |
| Arkansas | 11,300 | ,000 | 20,300 | -- | -- | -- | 11,300 | 9,000 | 20,300 |
| California | 120,000 | 22,400 | 142,000 | 592 | 210 | 802 | 120,000 | 22,600 | 143,000 |
| Colorado | 31,700 | 9,810 | 41,600 | 10,100 | 6,300 | 16,400 | 41,900 | 16,100 | 58,000 |
| Connecticut | 7,140 | 86 | 7,230 | -- | -- | -- | 7,140 | 86 | 7,230 |
| Delaware | 1,000 | -- | 1,000 | -- | -- | -- | 1,000 | -- | 1,000 |
| Florida | 189,000 | 224,000 | 414,000 | -- | -- | -- | 189,000 | 224,000 | 414,000 |
| Georgia | 14,900 | 7,730 | 22,600 | W | -- | W | 14,900 | 7,730 | 22,600 |
| Hawaii | 449 | -- | 449 | -- | -- | -- | 449 | -- | 449 |
| Idaho | 16,900 | 44,000 | 60,900 | 974 | 178 | 1,150 | 17,800 | 44,200 | 62,100 |
| Illinois | 30,500 | 365 | 30,900 | 204 | W | 204 | 30,700 | 365 | 31,100 |
| Indiana | 16,900 | 568 | 17,500 | W | -- | W | 16,900 | 568 | 17,500 |
| Iowa | 15,500 | 393 | 15,900 | 503 | W | 503 | 16,000 | 393 | 16,400 |
| Kansas | 13,300 | 798 | 14,100 | 1,170 | -- | 1,170 | 14,500 | 798 | 15,300 |
| Kentucky | 8,660 | 699 | 9,360 | 1 | 5 | 6 | 8,660 | 703 | 9,360 |
| Louisiana | 17,900 | 475 | 18,400 | 5,180 | W | 5,180 | 23,100 | 475 | 23,600 |
| Maine | 7,930 | W | 7,930 | -- | -- | -- | 7,930 | W | 7,930 |
| Maryland | 14,600 | 305 | 14,900 | -- | -- | -- | 14,600 | 305 | 14,900 |
| Massachusetts | 14,500 | 208 | 14,700 | -- | -- | -- | 14,500 | 208 | 14,700 |
| Michigan | 86,500 | 45,100 | 132,000 | W | -- | W | 86,500 | 45,100 | 132,000 |
| Minnesota | 155,000 | 40,100 | 195,000 | -- | -- | -- | 155,000 | 40,100 | 195,000 |
| Mississippi | 14,700 | 2,110 | 16,800 | -- | -- | -- | 14,700 | 2,110 | 16,800 |
| Missouri | 10,800 | 1,600 | 12,400 | 7,520 | 1,110 | 8,630 | 18,300 | 2,710 | 21,000 |
| Montana | 16,400 | 13,300 | 29,700 | 3,580 | 28 | 3,600 | 20,000 | 13,300 | 33,300 |
| Nebraska | 12,000 | 156 | 12,200 | -- | -- | -- | 12,000 | 156 | 12,200 |
| Nevada | 38,600 | 88,800 | 127,000 | 627 | 118 | 744 | 39,200 | 88,900 | 128,000 |
| New Hampshire | 5,650 | W | 5,650 | -- | -- | -- | 5,650 | W | 5,650 |
| New Jersey | 12,300 | W | 12,300 | W | W | W | 12,300 | W | 12,300 |
| New Mexico | 39,500 | 132,000 | 171,000 | 19,200 | 581 | 19,800 | 58,700 | 132,000 | 191,000 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| New York | 27,000 | 587 | 27,600 | 5,170 | W | 5,170 | 32,200 | 587 | 32,800 |
| North Carolina | 23,600 | 3,720 | 27,300 | | -- | | 23,600 | 3,720 | 27,300 |
| North Dakota | 6,490 | W | 6,490 | W | -- | W | 6,490 | W | 6,490 |
| Ohio | 35,400 | 1,660 | 37,000 | 3,970 | W | 3,970 | 39,300 | 1,660 | 41,000 |
| Oklahoma | 14,700 | 851 | 15,500 | - | - | - | 14,700 | 851 | 15,500 |
| Oregon | 17,400 | 4,810 | 22,200 | (3) | 3 | 3 | 17,400 | 4,810 | 22,200 |
| Pennsylvania | 16,200 | 852 | 17,000 | W | W | W | 16,200 | 852 | 17,000 |
| Rhode Island | 1,530 | -- | 1,530 | -- | -- | -- | 1,530 | - | 1,530 |
| South Carolina | 8,800 | 1,690 | 10,500 | -- | -- | -- | 8,800 | 1,690 | 10,500 |
| South Dakota | 7,080 | 839 | 7,920 | W | W | W | 7,080 | 839 | 7,920 |
| Tennessee | 11,000 | 3,450 | 14,500 | 6,770 | 681 | 7,450 | 17,800 | 4,130 | 21,900 |
| Texas | 71,900 | 10,100 | 82,000 | 335 | -- | 335 | 72,200 | 10,100 | 82,300 |
| Utah | 41,600 | 50,900 | 92,500 | 494 | 326 | 820 | 42,100 | 51,200 | 93,300 |
| Vermont | 4,750 | W | 4,750 | -- | -- | -- | 4,750 | W | 4,750 |
| Virginia | 10,400 | 926 | 11,400 | W | -- | W | 10,400 | 926 | 11,400 |
| Washington | 24,400 | 675 | 25,000 | W | (3) | W | 24,400 | 675 | 25,000 |
| West Virginia | 2,640 | 246 | 2,890 | 98 | 1 | 99 | 2,740 | 248 | 2,990 |
| Wisconsin | 18,800 | -- | 18,800 | -- | -- | -- | 18,800 | -- | 18,800 |
| Wyoming | 10,900 | 19,600 | 30,500 | 6,730 | W | 6,730 | 17,600 | 19,600 | 37,200 |
| Undistributed | 31 | 924 | 955 | 3,240 | 1,220 | 4,460 | 3,270 | 2,150 | 5,410 |
| Total[2] [3] | 1,480,000 | 901,000 | 2,380,000 | 96,800 | 11,000 | 108,000 | 1,570,000 | 912,000 | 2,490,000 |

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Excludes material from wells, ponds, or pumping operations.

[2] Data may not add to totals shown because of independent rounding.

[3] Includes estimated data in table 2.

## Table 4.—Value of principal mineral products and byproducts of surface and underground ores mined in the United States in 1984

(Value per ton)

| Ore | Surface |  |  | Underground |  |  | All mines |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | Principal mineral product | By-product | Total | Principal mineral product | By-product | Total | Principal mineral product | By-product | Total |
| METALS |  |  |  |  |  |  |  |  |  |
| Bauxite | $13.90 | W | $13.90 | -- | -- | -- | $13.90 | W | $13.90 |
| Copper | 8.38 | $1.11 | 9.49 | $7.83 | $3.22 | $11.04 | 8.31 | $1.36 | 9.67 |
| Gold: |  |  |  |  |  |  |  |  |  |
| Lode | 12.70 | 1.36 | 14.06 | 44.46 | 9.69 | 54.15 | 15.00 | 1.96 | 16.96 |
| Placer | 1.62 | -- | 1.62 | -- | -- | -- | 1.62 | -- | 1.62 |
| Iron ore | 12.56 | W | 12.56 | W | W | W | 12.56 | W | 12.56 |
| Lead | W | W | W | 28.73 | 17.38 | 46.12 | 28.73 | 17.38 | 46.11 |
| Silver | 10.06 | 1.40 | 11.46 | 45.26 | 11.41 | 56.67 | 30.59 | 7.24 | 37.83 |
| Titanium (ilmenite) | 3.27 | 3.94 | 7.21 | -- | -- | -- | 3.27 | 3.94 | 7.21 |
| Tungsten | 1.07 | -- | 1.07 | 40.49 | W | 40.49 | 40.26 | W | 40.26 |
| Zinc | -- | -- | -- | 34.25 | W | 34.25 | 34.25 | W | 34.25 |
| Average[1] | 10.48 | .68 | 11.16 | 18.34 | 4.40 | 22.74 | 11.43 | 1.13 | 12.56 |
| INDUSTRIAL MINERALS |  |  |  |  |  |  |  |  |  |
| Asbestos | 19.01 | -- | 19.01 | -- | -- | -- | 19.01 | -- | 19.01 |
| Barite | 29.70 | W | 29.70 | -- | -- | -- | 29.70 | W | 29.70 |
| Clays | 22.97 | .14 | 23.11 | 11.25 | -- | 11.25 | 22.89 | .14 | 23.03 |
| Diatomite | 67.57 | -- | 67.57 | -- | -- | -- | 67.57 | -- | 67.57 |
| Feldspar | 8.84 | 29.51 | 38.35 | -- | -- | -- | 8.84 | 29.51 | 38.35 |
| Fluorspar | W | -- | W | 80.80 | W | 80.80 | 80.80 | W | 80.80 |
| Gypsum | 7.60 | -- | 7.60 | 6.97 | -- | 6.97 | 7.49 | -- | 7.49 |
| Mica (scrap) | 7.01 | W | 7.01 | -- | -- | -- | 7.01 | W | 7.01 |
| Perlite | 15.43 | -- | 15.43 | W | -- | W | 15.43 | -- | 15.43 |
| Phosphate rock | 3.63 | -- | 3.63 | W | -- | W | 3.63 | -- | 3.63 |
| Potassium salts | -- | -- | -- | 13.30 | -- | 13.30 | 13.30 | -- | 13.30 |
| Pumice | 9.83 | -- | 9.83 | -- | -- | -- | 9.83 | -- | 9.83 |
| Salt | 4.39 | -- | 4.39 | 8.86 | 1.86 | 10.72 | 8.66 | 1.78 | 10.44 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sand and gravel | 3.25 | .02 | 3.27 | | -- | | 3.25 | .02 | 3.27 |
| Sodium carbonate (natural) | -- | -- | -- | 65.75 | -- | 65.75 | 65.75 | -- | 65.75 |
| Talc, soapstone, pyrophyllite | 13.49 | W | 13.49 | 15.13 | W | 15.13 | 13.69 | W | 13.69 |
| Average[1] | 4.68 | .08 | 4.76 | 19.24 | .90 | 20.14 | 5.23 | .11 | 5.34 |
| Average, metals and industrial minerals[1] | 6.17 | .24 | 6.41 | 18.75 | 2.82 | 20.51 | 6.93 | .39 | 7.33 |
| Average, industrial minerals (excluding sand and gravel)[1] | 7.59 | .22 | 7.81 | 19.24 | .90 | 20.14 | 8.83 | .29 | 9.12 |
| Average, metals and industrial minerals (excluding sand and gravel)[1] | 9.07 | .46 | 9.52 | 18.75 | 2.82 | 21.57 | 10.17 | .73 | 10.90 |

W Withheld to avoid disclosing company proprietary data.

[1] Includes unpublished data.

## Table 5.—Crude ore and total material handled at surface and underground mines in the United States in 1984, by commodity

(Percent)

| Commodity | Crude ore |  | Total material |  |
|---|---|---|---|---|
|  | Surface | Underground | Surface | Underground |
| METALS |  |  |  |  |
| Antimony | -- | 100.0 | -- | 100.0 |
| Bauxite | 100.0 | -- | 100.0 | -- |
| Copper | 88.5 | 11.5 | 95.6 | 4.4 |
| Gold: |  |  |  |  |
| Lode | 92.7 | 7.3 | 97.8 | 2.2 |
| Placer | 99.7 | .3 | 97.7 | 2.3 |
| Iron ore | [1]100.0 | W | [1]100.0 | W |
| Lead | W | [2]100.0 | W | [2]100.0 |
| Manganiferous ore | 100.0 | -- | 100.0 | -- |
| Molybdenum | [1]100.0 | W | [1]100.0 | W |
| Nickel | 100.0 | -- | 100.0 | -- |
| Silver | 39.0 | 61.0 | 78.1 | 21.9 |
| Tungsten | .6 | 99.4 | 1.5 | 98.5 |
| Uranium | 64.6 | 35.4 | 95.3 | 4.7 |
| Zinc | -- | 100.0 | -- | 100.0 |
| Average[3] | 88.1 | 11.9 | 93.9 | 6.1 |
| INDUSTRIAL MINERALS |  |  |  |  |
| Abrasives[4] | [1]100.0 | W | [1]100.0 | W |
| Asbestos | 100.0 | -- | 100.0 | -- |
| Barite | 100.0 | -- | 100.0 | -- |
| Clays | 99.3 | .7 | 99.6 | .4 |
| Diatomite | 100.0 | -- | 100.0 | -- |
| Feldspar | 100.0 | -- | 100.0 | -- |
| Fluorspar | W | [2]100.0 | W | [2]100.0 |
| Gypsum | 84.6 | 15.4 | 84.6 | 15.4 |
| Mica (scrap) | 100.0 | -- | 100.0 | -- |
| Millstones | 100.0 | -- | 100.0 | -- |
| Olivine | 100.0 | -- | 100.0 | -- |
| Perlite | [1]100.0 | W | [1]100.0 | W |
| Phosphate rock | [1]100.0 | W | [1]100.0 | W |
| Potassium salts | -- | 100.0 | -- | 100.0 |
| Pumice | 100.0 | -- | 100.0 | -- |
| Salt | 6.4 | 93.6 | 6.2 | 93.8 |
| Sand and gravel | 100.0 | -- | 100.0 | -- |
| Sodium carbonate (natural) | -- | 100.0 | -- | 100.0 |
| Talc, soapstone, pyrophyllite | 90.0 | 10.0 | 98.3 | 1.7 |
| Vermiculite | 100.0 | -- | 100.0 | -- |
| Average[3] | 96.3 | 3.7 | 97.0 | 3.0 |
| Average, metals and industrial minerals[3] | 93.9 | 6.1 | 95.7 | 4.3 |

W Withheld to avoid disclosing company proprietary data; included with "Surface" or "Underground."

[1] Includes underground; the Bureau of Mines is not at liberty to publish separately.

[2] Includes surface; the Bureau of Mines is not at liberty to publish separately.

[3] Includes unpublished data.

[4] Abrasive stone, emery, garnet, and tripoli.

### Table 6.—Crude ore and total material handled at surface and underground mines in the United States in 1984, by State

(Percent)

| State | Crude ore |  | Total material |  |
|---|---|---|---|---|
|  | Surface | Under-ground | Surface | Under-ground |
| Alabama | 100.0 | -- | 100.0 | -- |
| Alaska | 100.0 | -- | 100.0 | -- |
| Arizona | 88.2 | 11.8 | 93.7 | 6.3 |
| Arkansas | 100.0 | -- | 100.0 | -- |
| California | 99.5 | .5 | 99.4 | .6 |
| Colorado | 75.8 | 24.2 | 71.7 | 28.3 |
| Connecticut | 100.0 | -- | 100.0 | -- |
| Delaware | 100.0 | -- | 100.0 | -- |
| Florida | 100.0 | -- | 100.0 | -- |
| Georgia | [1]100.0 | W | [1]100.0 | W |
| Hawaii | 100.0 | -- | 100.0 | -- |
| Idaho | 94.5 | 5.5 | 98.1 | 1.9 |
| Illinois | 99.3 | .7 | 99.1 | .9 |
| Indiana | 94.0 | 6.0 | 44.2 | 55.8 |
| Iowa | 96.9 | 3.1 | 96.9 | 3.1 |
| Kansas | 91.9 | 8.1 | 92.4 | 7.6 |
| Kentucky | 100.0 | -- | 99.9 | .1 |
| Louisiana | 77.6 | 22.4 | 77.9 | 22.1 |
| Maine | 100.0 | -- | 100.0 | -- |
| Maryland | 100.0 | -- | 100.0 | -- |
| Massachusetts | 100.0 | -- | 100.0 | -- |
| Michigan | [1]100.0 | W | [1]100.0 | W |
| Minnesota | 100.0 | -- | 100.0 | -- |
| Mississippi | 100.0 | -- | 100.0 | -- |
| Missouri | 58.9 | 41.1 | 58.9 | 41.1 |
| Montana | 82.1 | 17.9 | 89.2 | 10.8 |
| Nebraska | 100.0 | -- | 100.0 | -- |
| Nevada | 98.4 | 1.6 | 99.4 | .6 |
| New Hampshire | 100.0 | -- | 100.0 | -- |
| New Jersey | [1]100.0 | W | [1]100.0 | W |
| New Mexico | 67.3 | 32.7 | 89.7 | 10.3 |
| New York | 84.0 | 16.0 | 83.3 | 16.7 |
| North Carolina | 100.0 | -- | 100.0 | -- |
| North Dakota | [1]100.0 | W | [1]100.0 | W |
| Ohio | 89.9 | 10.1 | 89.4 | 10.6 |
| Oklahoma | 100.0 | -- | 100.0 | -- |
| Oregon | 100.0 | -- | 100.0 | -- |
| Pennsylvania | [1]100.0 | W | [1]100.0 | W |
| Rhode Island | 100.0 | -- | 100.0 | -- |
| South Carolina | 100.0 | -- | 100.0 | -- |
| South Dakota | 80.7 | 19.3 | 79.9 | 20.1 |
| Tennessee | 62.0 | 38.0 | 66.0 | 34.0 |
| Texas | 99.5 | .5 | 99.6 | .4 |
| Utah | 98.8 | 1.2 | 99.1 | .9 |
| Vermont | 100.0 | -- | 100.0 | -- |
| Virginia | [1]100.0 | W | [1]100.0 | W |
| Washington | [1]100.0 | W | [1]100.0 | W |
| West Virginia | 96.4 | 3.6 | 96.7 | 3.3 |
| Wisconsin | 100.0 | -- | 100.0 | -- |
| Wyoming | 61.7 | 38.3 | 81.9 | 18.1 |
| Average[2] | 93.9 | 6.1 | 95.7 | 4.3 |

W Withheld to avoid disclosing company proprietary data; included with "Surface."

[1] Includes underground; the Bureau of Mines is not at liberty to publish separately.

[2] Includes unpublished data.

## Table 7.—Number of domestic metal and industrial mineral mines[1] in the United States in 1984, by commodity

| Commodity | Total number of mines | Less than 1,000 tons | 1,000 to 10,000 tons | 10,000 to 100,000 tons | 100,000 to 1,000,000 tons | 1,000,000 to 10,000,000 tons | More than 10,000,000 tons |
|---|---|---|---|---|---|---|---|
| METALS | | | | | | | |
| Bauxite | 6 | -- | -- | 4 | 2 | -- | -- |
| Copper | 25 | 2 | 3 | 3 | -- | 9 | 8 |
| Gold: | | | | | | | |
| Lode | 82 | 35 | 8 | 8 | 20 | 10 | 1 |
| Placer | 31 | 5 | 8 | 11 | 5 | 2 | -- |
| Iron ore | 21 | -- | 1 | 3 | 4 | 5 | 8 |
| Lead | 13 | 3 | 1 | 1 | 6 | 2 | -- |
| Silver | 33 | 9 | 7 | 7 | 8 | 2 | -- |
| Titanium (ilmenite) | 3 | -- | -- | -- | 2 | 1 | -- |
| Tungsten | 9 | 5 | 2 | -- | 2 | -- | -- |
| Uranium | 41 | 9 | 9 | 17 | 6 | -- | -- |
| Zinc | 11 | -- | 1 | 1 | 7 | 2 | -- |
| Other[2] | 21 | 2 | 5 | 5 | 4 | 5 | -- |
| Total | 296 | 70 | 45 | 60 | 66 | 38 | 17 |
| INDUSTRIAL MINERALS | | | | | | | |
| Abrasives[3] | 12 | 2 | 4 | 5 | 1 | -- | -- |
| Asbestos | 3 | -- | -- | -- | 3 | -- | -- |
| Barite | 15 | -- | 4 | 7 | 4 | -- | -- |
| Clays | 944 | 56 | 226 | 531 | 131 | -- | -- |
| Diatomite | 10 | -- | 2 | 4 | 4 | -- | -- |
| Feldspar | 15 | -- | 3 | 5 | 6 | 1 | -- |
| Fluorspar | 4 | 1 | 2 | -- | 1 | -- | -- |
| Gypsum | 69 | 2 | 4 | 23 | 38 | 2 | -- |
| Mica (scrap) | 12 | 1 | 2 | 5 | 4 | -- | -- |
| Perlite | 11 | -- | 3 | 5 | 3 | -- | -- |
| Phosphate rock | 36 | -- | -- | 1 | 11 | 17 | 7 |
| Potassium salts | 5 | -- | -- | -- | 1 | 4 | -- |
| Pumice | 23 | 4 | 9 | 7 | 3 | -- | -- |
| Salt | 19 | -- | 3 | 4 | 6 | 6 | -- |
| Sand and gravel | 6,076 | 111 | 913 | 3,020 | 1,960 | 71 | 1 |
| Sodium carbonate (natural) | 5 | -- | -- | -- | 2 | 3 | -- |
| Talc, soapstone, pyrophyllite | 40 | 8 | 14 | 14 | 4 | -- | -- |
| Other[4] | 31 | 7 | 3 | 15 | 5 | 1 | -- |
| Total | 7,330 | 192 | 1,192 | 3,646 | 2,187 | 105 | 8 |
| Grand total | 7,626 | 262 | 1,237 | 3,706 | 2,253 | 143 | 25 |

[1] Excludes wells, ponds, or pumping operations.

[2] Includes antimony, beryllium, manganiferous ore, mercury, molybdenum, rare-earth metals, and tin.

[3] Includes abrasive stone, emery, garnet, and tripoli.

[4] Includes aplite, boron minerals, graphite, greensand marl, iron oxide pigments (crude), kyanite, magnesite, millstones, olivine, vermiculite, and wollastonite.

### Table 8.—Twenty-five leading metal and industrial mineral[1] mines in the United States in 1984, in order of output of crude ore

| Mine | State | Operator | Commodity | Mining method |
|---|---|---|---|---|
| | | METALS | | |
| Morenci | Arizona | Phelps Dodge Corp | Copper | Open pit. |
| Minntac | Minnesota | United States Steel Corp | Iron ore | Do. |
| Sierrita | Arizona | Duval Sierrita Corp | Copper | Do. |
| Empire | Michigan | Empire Iron Mining | Iron ore | Do. |
| Utah Copper | Utah | Kennecott | Copper | Do. |
| Hibbing Taconite | Minnesota | Pickands Mather & Co | Iron ore | Do. |
| San Manuel | Arizona | Magma Copper Co | Copper | Caving and open pit. |
| Tilden | Michigan | Tilden Mining Co | Iron ore | Open pit. |
| Tyrone | New Mexico | Phelps Dodge Corp | Copper | Do. |
| Erie Commercial | Minnesota | Pickands Mather & Co | Iron ore | Do. |
| Chino | New Mexico | Chino Mines Co | Copper | Do. |
| Ray Pit | Arizona | Kennecott | do | Do. |
| Thunderbird | Minnesota | Oglebay Norton Co | Iron ore | Do. |
| Pinto Valley | Arizona | Pinto Valley Copper Corp | Copper | Do. |
| Round Mountains | Nevada | Copper Range Co | Lode gold | Do. |
| Peter Mitchell | Minnesota | Reserve Mining Co | Iron ore | Do. |
| National Pellet Project-Itasca. | do | The Hanna Mining Co | do | Do. |
| Green Cove | Florida | Associated Minerals Corp | Titanium | Dredging. |
| Eisenhower | Arizona | ASARCO Incorporated | Copper | Open pit. |
| Minorca | Minnesota | Inland Steel Mining Co | Iron ore | Do. |
| Inspiration | Arizona | Inspiration Consolidated Copper Co. | Copper | Do. |
| National Pellet Project-St. Louis. | Minnesota | The Hanna Mining Co | Iron ore | Do. |
| Butler Taconite | do | do | do | Do. |
| Henderson | Colorado | Climax Molybdenum Co., a division of AMAX Inc. | Molybdenum | Caving and open pit. |
| New Cornelia | Arizona | Phelps Dodge Corp | Copper | Open pit. |
| | | INDUSTRIAL MINERALS[2] | | |
| Noralyn | Florida | International Minerals & Chemical Corp. | Phosphate rock. | Open pit. |
| Kingsford | do | do | do | Do. |
| Ft. Green | do | Williams Co | do | Do. |
| Hookers | do | W. R. Grace & Co | do | Do. |
| Ft. Meade | do | Mobil Oil Corp | do | Do. |
| Lee Creek | North Carolina | Texasgulf Inc | do | Do. |
| Haynsworth | Florida | American Cyanamid Co | do | Do. |
| Clear Spring | do | International Minerals & Chemical Corp. | do | Do. |
| Lonesome | do | American Cyanamid Co | do | Do. |
| Suwanee | do | Occidental Petroleum Corp | do | Do. |
| Big Four | do | AMAX Phosphate Inc.,a division of AMAX Inc. | do | Do. |
| Wingate Creek | do | Beker Industries Corp | do | Do. |
| Swift Creek | do | Occidental Petroleum Corp | do | Do. |
| International | New Mexico | International Minerals & Chemical Corp. | Potassium salts. | Stopes. |
| Payne Creek | Florida | Agrico Chemical Co | Phosphate rock. | Open pit. |
| Hardee | do | C. F. Mining Corp | do | Do. |
| Irwindale | California | Koppers Co., Blue Diamond Materials. | Sand and gravel. | Dredging. |
| Radum | do | Koppers Co., Kaiser Sand and Gravel. | do | Do. |
| AMAX | New Mexico | AMAX Chemical Corp., a division of AMAX Inc. | Potassium salts. | Stopes. |
| St. Lucie | Florida | General Development Corp | Sand and gravel. | Dredging. |
| Saddle Creek | do | Agrico Chemical Co | Phosphate rock. | Open pit. |
| Hobbs | New Mexico | New Mexico Potash Corp | Potassium salts. | Do. |
| Retsof | New York | International Salt Co | Salt | Stopes. |
| Rockland | Florida | USS Agri-Chemicals | Phosphate rock. | Open pit. |
| Perkins | California | Teichert Aggregates | Sand and gravel. | Dredging. |

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[1] Excludes brines and materials from wells.

[2] Crushed and broken and dimension stone were not available in 1984 because of biennial canvassing.

## Table 9.—Twenty-five leading metal and industrial mineral[1] mines in the United States in 1984, in order of output of total materials handled

| Mine | State | Operator | Commodity | Mining method |
|---|---|---|---|---|
| | | METALS | | |
| Tyrone | New Mexico | Phelps Dodge Corp | Copper | Open pit. |
| Morenci | Arizona | do | do | Do. |
| Utah Copper | Utah | Kennecott | do | Do. |
| Sierrita | Arizona | Duval Sierrita Corp | do | Do. |
| Empire | Michigan | Empire Iron Mining | Iron ore | Do. |
| Chino | New Mexico | Chino Mines Co | Copper | Do. |
| Inspiration | Arizona | Inspiration Consolidated Copper Co. | do | Do. |
| Ray Pit | do | Kennecott | do | Do. |
| Minntac | Minnesota | United States Steel Corp | Iron ore | Do. |
| Hibbing Taconite | do | Pickands Mather & Co | do | Do. |
| Tilden | Michigan | Tilden Mining Co | do | Do. |
| Thompson Creek | Idaho | Cyprus Mines Corp | Molybdenum | Do. |
| Battle Mountain | Nevada | Battle Mountain Gold Co | Lode gold | Do. |
| Thunderbird | Minnesota | Oglebay Norton Co | Iron ore | Do. |
| San Manuel | Arizona | Magma Copper Co | Copper | Caving and open pit. |
| Pinto Valley | do | Pinto Valley Copper Co | do | Open pit. |
| Erie Commercial | Minnesota | Pickands Mather & Co | Iron ore | Do. |
| Candelaria | Nevada | Nerco Minerals Co | Silver | Do. |
| Eisenhower | Arizona | ASARCO Incorporated | Copper | Do. |
| Mercur | Utah | Barrick Mercur Gold Mines Inc. | Lode gold | Do. |
| Climax | Colorado | Climax Molybdenum Co., a division of AMAX Inc. | Molybdenum | Do. |
| Henderson | do | do | do | Caving and open pit. |
| Maggie Creek | Nevada | Carlin Gold Mining Co | Lode gold | Open pit. |
| Round Mountains | do | Copper Range Co | do | Do. |
| Peter Mitchell | Minnesota | Reserve Mining Co | Iron ore | Do. |
| | | INDUSTRIAL MINERALS[2] | | |
| Noralyn | Florida | International Minerals & Chemical Corp. | Phosphate rock. | Open pit. |
| Ft. Green | do | Williams Co | do | Do. |
| Kingsford | do | International Minerals & Chemical Corp. | do | Do. |
| Suwannee | do | Occidental Petroleum Corp | do | Do. |
| Haynsworth | do | American Cyanamid Co | do | Do. |
| Clear Spring | do | International Minerals & Chemical Corp. | do | Do. |
| Lonesome | do | American Cyanamid Co | do | Do. |
| Hookers | do | W. R. Grace & Co | do | Do. |
| Wingate Creek | do | Beker Industries Corp | do | Do. |
| Swift Creek | do | Occidental Petroleum Corp | do | Do. |
| Big Four | do | AMAX Phosphate Inc., a division of AMAX Inc. | do | Do. |
| Ft. Meade | do | Mobil Oil Corp | do | Do. |
| Lee Creek | North Carolina | Texasgulf Inc | do | Do. |
| Ft. Meade | Florida | Gardinier Inc | do | Do. |
| Hardee | do | C. F. Mining Corp | do | Do. |
| Mabie Canyon | Idaho | Conda Partnership | do | Do. |
| Saddle Creek | Florida | Agrico Chemical Co | do | Do. |
| Vernal | Utah | Chevron Resources Co | do | Do. |
| International | New Mexico | International Minerals & Chemical Corp. | Potassium salts. | Stopes. |
| Payne Creek | Florida | Agrico Chemical Co | Phosphate rock. | Open pit. |
| Henry | Idaho | Monsanto Co | do | Do. |
| Copperopolis | California | Calaveras Asbestos Corp | Asbestos | Do. |
| Irwindale | do | Koppers Co., Blue Diamond Materials. | Sand and gravel. | Dredging. |
| Conda | Idaho | J. R. Simplot Co | Phosphate rock. | Open pit. |
| Radum | California | Koppers Co., Kaiser Sand and Gravel. | Sand and gravel. | Dredging. |

[1] Excludes brines and materials from wells.

[2] Crushed and broken and dimension stone were not available in 1984 because of biennial canvassing.

**Table 10.—Ore treated or sold per unit of marketable product at surface and underground mines[1] in the United States in 1984, by commodity**

| Commodity | | Surface | | | Underground | | | Total[2] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ore treated (thousand short tons) | Marketable product (units) | Ratio of units of ore to units of marketable product | Ore treated (thousand short tons) | Marketable product (units) | Ratio of units of ore to units of marketable product | Ore treated (thousand short tons) | Marketable product (units) | Ratio of units of ore to units of marketable product |
| **METALS** | | | | | | | | | | |
| Bauxite | thousand long tons | 1,130 | 843 | 1.3:1 | -- | -- | -- | 1,130 | 843 | 1.3:1 |
| Copper | thousand short tons | 166,000 | 1,040 | 159.6:1 | 22,200 | 130 | 170.8:1 | 188,000 | 1,170 | 160.8:1 |
| Gold: | | | | | | | | | | |
| Lode | thousand troy ounces | 37,900 | 1,330 | 28.3:1 | 2,950 | 364 | 8.1:1 | 40,900 | 1,700 | 24.0:1 |
| Placer | do | 8,480 | 38 | 223.2:1 | -- | -- | -- | 8,480 | 38 | 223.2:1 |
| Iron ore | thousand long tons | 175,000 | 4,920 | 3.5:1 | W | W | W | 175,000 | 4,920 | 3.5:1 |
| Lead | thousand pounds | W | W | W | 5,460 | 307 | 17.7:1 | 5,460 | 307 | 17.7:1 |
| Silver | thousand troy ounces | 3,440 | 4,250 | .8:1 | 4,820 | 26,800 | .1:1 | 8,260 | 31,000 | .2:1 |
| Zinc | thousand short tons | -- | -- | -- | 5,810 | 205 | 28.3:1 | 5,810 | 205 | 28.3:1 |
| **INDUSTRIAL MINERALS** | | | | | | | | | | |
| Asbestos | do | 1,270 | 63 | 20.1:1 | -- | -- | -- | 1,270 | 63 | 20.1:1 |
| Barite | do | 849 | 771 | 1.1:1 | -- | -- | -- | 849 | 771 | 1.1:1 |
| Clays | do | 44,200 | 43,000 | 1.0:1 | 331 | 331 | 1.0:1 | 44,600 | 43,300 | 1.0:1 |
| Diatomite | do | 1,790 | 628 | 2.8:1 | -- | -- | -- | 1,790 | 628 | 2.8:1 |
| Feldspar | do | 2,610 | 695 | 3.7:1 | -- | -- | -- | 2,610 | 695 | 3.7:1 |
| Gypsum | do | 12,600 | 11,700 | 1.1:1 | 2,580 | 2,580 | 1.0:1 | 15,200 | 14,300 | 1.1:1 |
| Mica (scrap) | do | 806 | 117 | 6.8:1 | -- | -- | -- | 806 | 117 | 6.8:1 |
| Perlite | do | 1,070 | 494 | 2.1:1 | W | W | W | 1,070 | 494 | 2.1:1 |
| Phosphate rock | do | 324,000 | 54,000 | 5.9:1 | W | W | W | 324,000 | 54,000 | 5.9:1 |
| Potassium salts | do | -- | -- | -- | 15,300 | 1,560 | 9.8:1 | 15,300 | 1,560 | 9.8:1 |
| Pumice | do | 501 | 501 | 1.0:1 | -- | -- | -- | 501 | 501 | 1.0:1 |
| Salt | do | 967 | 620 | 1.5:1 | 21,000 | 13,100 | 1.6:1 | 22,000 | 13,700 | 1.6:1 |
| Sand and gravel | do | 804,000 | 799,000 | 1.0:1 | -- | -- | -- | 804,000 | 799,000 | 1.0:1 |
| Sodium carbonate (natural) | do | -- | -- | -- | 6,730 | 6,730 | 1.0:1 | 6,730 | 6,730 | 1.0:1 |
| Talc, soapstone, pyrophyllite | do | 1,420 | 994 | 1.4:1 | 207 | 205 | 1.9:1 | 1,630 | 1,100 | 1.4:1 |

W Withheld to avoid disclosing company proprietary data.

[1] Excludes wells, ponds, or pumping operations.

[2] Data may not add to totals shown because of independent rounding.

## Table 11.—Material handled per unit of marketable product at surface and underground mines[1] in the United States in 1984, by commodity

| Commodity | | Surface | | | Underground | | | Total[2] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Total material handled[3] (thousand short tons) | Marketable product (units) | Ratio of units of material handled to units of marketable product[4] | Total material handled[3] (thousand short tons) | Marketable product (units) | Ratio of units of material handled to units of marketable product[4] | Total material handled[3] (thousand short tons) | Marketable product (units) | Ratio of units of material handled to units of marketable product[4] |
| **METALS** | | | | | | | | | | |
| Bauxite | thousand long tons | 9,210 | 843 | 1.3:1 | -- | -- | -- | 9,210 | 843 | 1.3:1 |
| Copper | thousand short tons | 483,000 | 1,040 | 408.1:1 | 22,400 | 130 | 170.5:1 | 505,000 | 1,170 | 381.6:1 |
| Gold: | | | | | | | | | | |
| Lode | thousand troy ounces | 152,000 | 1,330 | 86.1:1 | 3,450 | 364 | 8.7:1 | 155,000 | 1,700 | 69.5:1 |
| Placer | do | 8,810 | 38 | 230.3:1 | 211 | -- | -- | 9,020 | 38 | 231.2:1 |
| Iron ore | thousand long tons | 260,000 | 49,200 | 5.3:1 | W | W | W | 260,000 | 49,200 | 5.3:1 |
| Lead | thousand pounds | 31 | -- | -- | 6,690 | 307 | 18.4:1 | 6,720 | 307 | 18.4:1 |
| Silver | thousand troy ounces | 19,000 | 4,250 | 2.7:1 | 5,320 | 26,800 | .2:1 | 24,300 | 31,000 | .5:1 |
| Zinc | thousand short tons | -- | -- | -- | 6,760 | 205 | 31.8:1 | 6,760 | 205 | 31.8:1 |
| **INDUSTRIAL MINERALS** | | | | | | | | | | |
| Asbestos | do | 6,170 | 63 | 75.9:1 | -- | -- | -- | 6,170 | 63 | 75.9:1 |
| Barite | do | 1,650 | 771 | 2.1:1 | -- | -- | -- | 1,650 | 771 | 2.1:1 |
| Clays | do | [e]82,600 | 43,000 | 1.9:1 | [e]336 | 331 | 1.0:1 | [e]83,000 | 43,300 | 1.9:1 |
| Diatomite | do | 6,790 | 628 | 10.7:1 | -- | -- | -- | 6,790 | 628 | 10.7:1 |
| Feldspar | do | 3,870 | 695 | 5.6:1 | -- | -- | -- | 3,870 | 695 | 5.6:1 |
| Gypsum | do | 14,100 | 11,700 | 1.2:1 | 2,580 | 2,580 | 1.0:1 | 16,700 | 14,300 | 1.2:1 |
| Mica (scrap) | do | 1,720 | 117 | 13.9:1 | -- | -- | -- | 1,720 | 117 | 13.9:1 |
| Perlite | do | 989 | 494 | 1.9:1 | W | W | W | 989 | 494 | 1.9:1 |
| Phosphate rock | do | 411,000 | 54,000 | 7.6:1 | W | W | W | 411,000 | 54,000 | 7.6:1 |
| Potassium salts | do | -- | -- | -- | 15,800 | 1,560 | 10.1:1 | 15,800 | 1,560 | 10.1:1 |
| Pumice | do | 589 | 501 | 1.2:1 | -- | -- | -- | 589 | 501 | 1.2:1 |
| Salt | do | 970 | 620 | 1.6:1 | 14,700 | 13,100 | 1.1:1 | 15,700 | 13,700 | 1.1:1 |
| Sand and gravel | do | 804,000 | 799,000 | 1.0:1 | -- | -- | -- | 804,000 | 799,000 | 1.0:1 |
| Sodium carbonate (natural) | do | -- | -- | -- | 6,730 | 6,730 | 1.0:1 | 6,730 | 6,730 | 1.0:1 |
| Talc, soapstone, pyrophyllite | do | 6,450 | 994 | 5.4:1 | 113 | 105 | 1.1:1 | 6,560 | 1,100 | 5.0:1 |

[e] Estimated. W Withheld to avoid disclosing company proprietary data.

[1] Excludes material from wells, ponds, or pumping operations.

[2] Data may not add to totals shown because of independent rounding.

[3] Includes material from development and exploration activities.

[4] Material from development and exploration activities is excluded from the ratio calculation.

## Table 12.—Mining methods used in open pit mining in the United States in 1984, by commodity

(Percent)

| Commodity | Total material handled: Preceded by drilling and blasting | Total material handled: Not preceded by drilling and blasting[1] |
|---|---|---|
| METALS | | |
| Bauxite | 92 | 8 |
| Copper | 95 | 5 |
| Gold: | | |
| Lode | 97 | 3 |
| Placer | 1 | 99 |
| Iron ore | 95 | 5 |
| Manganiferous ore | -- | 100 |
| Mercury | 15 | 85 |
| Molybdenum | 100 | -- |
| Rare-earth metals | 100 | -- |
| Silver | 85 | 15 |
| Titanium (ilmenite) | -- | 100 |
| Tungsten | 5 | 95 |
| Uranium | 34 | 66 |
| INDUSTRIAL MINERALS | | |
| Aplite | 15 | 85 |
| Asbestos | 62 | 38 |
| Barite | 74 | 26 |
| Clays | -- | 100 |
| Diatomite | -- | 100 |
| Feldspar | 66 | 34 |
| Fluorspar | 100 | -- |
| Gypsum | 98 | 2 |
| Iron oxide pigments (crude) | -- | 100 |
| Kyanite | 100 | -- |
| Magnesite | 100 | -- |
| Mica (scrap) | 16 | 84 |
| Millstones | 100 | -- |
| Olivine | 100 | -- |
| Perlite | 72 | 28 |
| Phosphate rock | 12 | 88 |
| Pumice | 48 | 52 |
| Salt | 8 | 92 |
| Sand and gravel | -- | 100 |
| Talc, soapstone, pyrophyllite | 96 | 4 |
| Vermiculite | 55 | 45 |
| Average | 40 | 60 |

[1] Includes drilling or cutting without blasting, dredging, mechanical excavation and nonfloat washing, and other surface mining methods.

## Table 13.—Development and exploration activity in the United States in 1984, by method

| Method | Metals: Feet | Metals: Percent of total[2] | Industrial minerals: Feet | Industrial minerals: Percent of total[2] | Total[1]: Feet | Total[1]: Percent of total[2] |
|---|---|---|---|---|---|---|
| DEVELOPMENT | | | | | | |
| Drifting, crosscutting, or tunneling | 373,000 | 67.9 | 11,300 | 100.0 | 384,000 | 68.5 |
| Raising | 63,400 | 11.6 | W | W | 63,400 | 11.3 |
| Shaft and winze sinking | 1,530 | .3 | W | W | 1,530 | .3 |
| Solution mining | 111,000 | 20.3 | W | W | 111,000 | 19.9 |
| Total[1] | 549,000 | 100.0 | 11,300 | 100.0 | 561,000 | 100.0 |
| EXPLORATION | | | | | | |
| Churn drilling | 27,000 | .6 | W | W | 27,100 | .6 |
| Diamond drilling | 836,000 | 17.9 | 112,000 | 61.5 | 949,000 | 19.5 |
| Percussion drilling | 982,000 | 21.0 | 31,000 | 17.0 | 1,010,000 | 20.9 |
| Rotary drilling | 2,540,000 | 54.4 | 39,400 | 21.6 | 2,580,000 | 53.2 |
| Trenching | 29,200 | .6 | W | W | 29,200 | .6 |
| Other drilling | 258,000 | 5.5 | -- | -- | 258,000 | 5.3 |
| Total[1] | 4,680,000 | 100.0 | 183,000 | 100.0 | 4,860,000 | 100.0 |
| Grand total[1] | 5,230,000 | XX | 194,000 | XX | 5,420,000 | XX |

W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1] Data may not add to totals shown because of independent rounding.

[2] Based on unrounded footage.

## Table 14.—Development and exploration in the United States in 1984, by commodity

(Feet)

| Commodity | Development | | | | | Exploration | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Shaft and winze sinking | Raising | Drifting, crosscutting, or tunneling | Solution mining | Total[1] | Diamond drilling | Churn drilling | Rotary drilling | Percussion drilling | Other drilling | Trenching | Total[1] |
| **METALS** | | | | | | | | | | | | |
| Copper | -- | 31,700 | 28,000 | -- | 59,700 | 6,640 | -- | 4,000 | -- | 100 | 160 | 10,900 |
| Gold: | | | | | | | | | | | | |
| Lode | 332 | 10,100 | 59,600 | -- | 70,000 | 218,000 | -- | 298,000 | 271,000 | 20,000 | 17,400 | 825,000 |
| Placer | 25 | 20 | 1,200 | -- | 1,250 | -- | W | -- | -- | 300 | W | 300 |
| Iron ore | -- | -- | W | -- | W | 15,700 | -- | -- | -- | -- | -- | 15,700 |
| Lead | -- | W | 24,700 | -- | 24,700 | 134,000 | W | -- | W | W | -- | 134,000 |
| Silver | 779 | 2,440 | 112,000 | -- | 116,000 | 102,000 | -- | 83,600 | 21,300 | 30,400 | W | 237,000 |
| Tungsten | W | -- | W | -- | W | 650 | -- | -- | W | -- | -- | 650 |
| Uranium | -- | 3,760 | 52,300 | 111,000 | 168,000 | 108,000 | -- | 1,560,000 | 281,000 | 167,000 | 1,650 | 2,110,000 |
| Zinc | W | 5,180 | 71,700 | -- | 76,800 | 83,400 | -- | 9,000 | 273,000 | 2,000 | 1,000 | 368,000 |
| Other[2] | 397 | 10,300 | 23,100 | -- | 33,800 | 169,000 | 27,000 | 594,000 | 136,000 | 38,000 | 8,160 | 972,000 |
| Total[1] | 1,530 | 63,400 | 373,000 | 111,000 | 549,000 | 836,000 | 27,100 | 2,540,000 | 982,000 | 258,000 | 29,200 | 4,680,000 |
| INDUSTRIAL MINERALS | | | | | | | | | | | | |
| All industrial minerals[3] | W | W | 11,300 | W | 11,300 | 112,000 | W | 39,400 | 31,000 | -- | W | 183,000 |
| Grand total[1] | 1,530 | 63,400 | 384,000 | 111,000 | 561,000 | 949,000 | 27,100 | 2,580,000 | 1,010,000 | 258,000 | 29,200 | 4,860,000 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Data may not add to totals shown because of independent rounding.

[2] Includes bauxite, beryllium, mercury, molybdenum, platinum-group metals, and items indicated by symbol W.

[3] Includes barite; boron minerals; diatomite; fluorspar; lime; potassium salts; salt; and talc, soapstone, and pyrophyllite.

### Table 15.—Development and exploration in the United States in 1984, by State

(Feet)

| State | Development | | | | | Exploration | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Shaft and winze sinking | Raising | Drifting, crosscutting, or tunneling | Solution mining | Total[1] | Diamond drilling | Churn drilling | Rotary drilling | Percussion drilling | Other drilling | Trenching | Total[1] |
| Alaska | -- | W | W | -- | W | 44,300 | W | W | -- | W | 1,170 | 45,500 |
| Arizona | W | W | 29,000 | -- | 29,000 | 16,000 | -- | 39,200 | 4,850 | W | 100 | 60,200 |
| California | 80 | 585 | 2,500 | -- | 3,160 | 16,800 | W | 368,000 | 66,100 | 1,440 | 9,400 | 462,000 |
| Colorado | -- | 5,690 | 29,400 | -- | 35,100 | 118,000 | -- | 68,900 | 115,000 | 18,200 | 250 | 321,000 |
| Idaho | 729 | W | 14,800 | -- | 15,500 | 13,400 | -- | W | -- | -- | -- | 13,400 |
| Missouri | -- | -- | 25,100 | -- | 25,100 | W | W | -- | -- | W | -- | W |
| Montana | 30 | W | 487 | -- | 517 | 125,000 | -- | W | 10 | 365 | 2,540 | 128,000 |
| Nevada | -- | 2,490 | 7,870 | -- | 10,400 | 12,300 | -- | 318,000 | 263,000 | 33,300 | 13,800 | 640,000 |
| New Mexico | -- | 9,770 | 58,600 | -- | 68,300 | 14,600 | -- | 190,000 | W | W | -- | 205,000 |
| Oregon | -- | -- | 509 | -- | 509 | W | -- | W | -- | 100 | 50 | 150 |
| South Dakota | -- | W | W | -- | W | W | -- | W | 1,500 | -- | -- | 1,500 |
| Tennessee | -- | W | 41,000 | -- | 41,000 | W | -- | -- | 273,000 | -- | -- | 273,000 |
| Texas | -- | -- | -- | 108,000 | 108,000 | W | -- | 955,000 | -- | -- | -- | 995,000 |
| Utah | W | W | 90,600 | -- | 90,600 | 48,900 | -- | 70,100 | 9,860 | 15,800 | 1,400 | 146,000 |
| Washington | -- | -- | 50 | -- | 50 | -- | -- | -- | W | -- | -- | W |
| Wyoming | -- | -- | W | 3,040 | 3,040 | 2,000 | -- | 211,000 | -- | -- | -- | 213,000 |
| Undistributed[2] | 694 | 44,900 | 84,500 | -- | 130,000 | 537,000 | 27,100 | 323,000 | 280,000 | 188,000 | 500 | 1,360,000 |
| Total[1] | 1,530 | 63,400 | 384,000 | 111,000 | 561,000 | 949,000 | 27,100 | 2,580,000 | 1,010,000 | 258,000 | 29,200 | 4,860,000 |

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Data may not add to totals shown because of independent rounding.

[2] Includes Alabama, Georgia, Illinois, Kentucky, Louisiana, Michigan, Minnesota, New Hampshire, New Jersey, New York, South Carolina, Virginia, and items indicated by symbol W.

## Table 16.—Total material (ore and waste) produced by mine development in the United States in 1984, by commodity and State

(Thousand short tons)

| | Shaft and winze sinking | Raising | Drifting, crosscutting, or tunneling | Stripping | Total[1] |
|---|---|---|---|---|---|
| **COMMODITY** | | | | | |
| **METALS** | | | | | |
| Copper | -- | 58 | 122 | 59,400 | 59,600 |
| Gold: | | | | | |
| Lode | W | W | 252 | 36,700 | 37,000 |
| Placer | (2) | (2) | 166 | 64 | 230 |
| Lead | -- | W | 1,040 | W | 1,040 |
| Silver | W | W | 259 | 7,360 | 7,620 |
| Uranium | -- | W | 234 | 5,170 | 5,400 |
| Zinc | W | W | 335 | -- | 335 |
| Other[3] | 17 | 1,650 | 4,700 | 10,620 | 17,000 |
| Total[1] | 17 | 1,710 | 7,110 | 119,000 | 128,000 |
| **INDUSTRIAL MINERALS** | | | | | |
| Talc, soapstone, pyrophyllite | -- | W | W | 1,060 | 1,060 |
| Other[4] | 2 | 4 | 102 | 1,740 | 1,850 |
| Total[1] | 2 | 4 | 102 | 2,800 | 2,910 |
| Grand total[1] | 19 | 1,720 | 7,210 | 122,000 | 131,000 |
| **STATE** | | | | | |
| Alaska | -- | W | W | 64 | 64 |
| Arkansas | -- | -- | -- | 8,080 | 8,080 |
| California | W | 2 | 180 | 10,900 | 11,100 |
| Colorado | -- | 1,540 | 4,700 | W | 6,240 |
| Idaho | W | W | 94 | 1,200 | 1,300 |
| Kentucky | 1 | (2) | 3 | -- | 5 |
| Missouri | -- | -- | 1,020 | 31 | 1,050 |
| Montana | (2) | W | 3 | 7,590 | 7,590 |
| Nevada | -- | W | 81 | 26,400 | 26,400 |
| New Mexico | -- | 35 | 276 | W | 311 |
| Oregon | -- | -- | 3 | W | 3 |
| Utah | W | W | 168 | W | 168 |
| Washington | -- | -- | (2) | W | (2) |
| Wyoming | -- | -- | W | 5,160 | 5,160 |
| Undistributed[5] | 18 | 140 | 685 | 62,800 | 63,600 |
| Total[1] | 19 | 1,720 | 7,210 | 122,000 | 131,000 |

W Withheld to avoid disclosing company proprietary data; included with "Other" or "Undistributed."

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 1/2 unit.

[3] Includes bauxite, beryllium, iron ore, molybdenum, nickel, tungsten, and items indicated by symbol W.

[4] Includes asbestos, barite, diatomite, fluorspar, mica (scrap), millstones, perlite, pumice, salt, wollastonite, and items indicated by symbol W.

[5] Includes Alabama, Arizona, Illinois, Louisiana, New Jersey, New York, North Carolina, South Dakota, Tennessee, Texas, Vermont, and items indicated by symbol W.

## Table 17.—U.S. industrial consumption of explosives

(Thousand pounds)

| Year | Coal mining[1] | Metal mining[1] | Quarrying and industrial mineral mining[1] | Total mineral industry | Construction work and other uses[2] | Total industrial |
|---|---|---|---|---|---|---|
| 1980 | 2,503,359 | 559,229 | 624,184 | 3,686,772 | 587,690 | 4,274,462 |
| 1981 | 2,249,262 | 695,449 | 493,771 | 3,438,482 | 902,567 | 4,341,049 |
| 1982 | 2,269,565 | 530,384 | 423,353 | 3,223,302 | 687,189 | 3,910,491 |
| 1983 | 2,126,263 | 481,129 | 467,710 | 3,075,102 | 655,150 | 3,730,252 |
| 1984 | 2,758,659 | 437,217 | 479,873 | 3,675,749 | 681,109 | 4,356,858 |

[1] Some quantities of this use are included with "Construction work and other uses" to avoid disclosing company proprietary data.

[2] Includes some quantities from "Coal mining," "Metal mining," and "Quarrying and industrial mineral mining."

Note.—Data for 1980 are not comparable to data for prior years owing to change in reporting by the Institute of Makers of Explosives.

**Table 18.—U.S. consumption of explosives in the minerals industry**

(Thousand pounds)

| Year | Coal mining | Metal mining | Quarrying and industrial mineral mining | Total |
|---|---|---|---|---|
| PERMISSIBLE EXPLOSIVES | | | | |
| 1980 | 52,476 | 81 | 716 | 53,273 |
| 1981 | 49,814 | 166 | 1,638 | 51,618 |
| 1982 | 43,401 | 287 | 1,317 | 45,005 |
| 1983 | 35,181 | 311 | 657 | 36,149 |
| 1984 | 37,721 | 195 | 345 | 38,261 |
| OTHER HIGH EXPLOSIVES | | | | |
| 1980 | 24,912 | 25,085 | 50,138 | 100,135 |
| 1981 | 22,314 | 23,384 | 43,223 | 88,921 |
| 1982 | 19,360 | 13,108 | 29,322 | 61,790 |
| 1983 | 17,964 | 8,861 | 31,833 | 58,658 |
| 1984 | 20,357 | 7,771 | 29,658 | 57,786 |
| WATER GELS AND SLURRIES | | | | |
| 1980 | 93,916 | 171,213 | 99,947 | 365,076 |
| 1981 | 99,796 | 174,528 | 86,671 | 360,995 |
| 1982 | 104,364 | 90,738 | 80,503 | 275,605 |
| 1983 | 94,578 | 49,699 | 94,261 | 238,538 |
| 1984 | 99,340 | 78,959 | 102,849 | 281,148 |
| AMMONIUM NITRATE: FUEL—MIXED AND UNPROCESSED | | | | |
| 1980 | 2,332,055 | 362,850 | 473,383 | 3,168,288 |
| 1981 | 2,077,338 | 497,371 | 362,239 | 2,936,948 |
| 1982 | 2,102,440 | 426,251 | 312,211 | 2,840,902 |
| 1983 | 1,978,540 | 422,258 | 340,959 | 2,741,757 |
| 1984 | 2,601,241 | 350,292 | 347,021 | 3,298,554 |
| TOTAL | | | | |
| 1980 | 2,503,359 | 559,229 | 624,184 | 3,686,772 |
| 1981 | 2,249,262 | 695,449 | 493,771 | 3,438,482 |
| 1982 | 2,269,565 | 530,384 | 423,353 | 3,223,302 |
| 1983 | 2,126,263 | 481,129 | 467,710 | 3,075,102 |
| 1984 | 2,758,659 | 437,217 | 479,873 | 3,675,749 |

## FROTH FLOTATION[40]

Froth flotation is a process for separating and selectively concentrating finely divided minerals. The process involves the crushing and grinding of ore to a fine enough size to liberate or free the mineral species from each other, followed by the selective recovery of the desired minerals by the injection of air into a mineral-water slurry. Chemicals added to the slurry as collectors are selectively adsorbed on the surfaces of particles of the desired minerals making them hydrophobic (water repellent) and allowing air bubbles to attach to the particles' surfaces. The hydrophobic particles are borne to the surface by air bubbles rising through the slurry and become concentrated in a surface froth, which is skimmed off to form a mineral concentrate. Conversely, other reagents called depressants may be added to the slurry to selectively render surfaces of the specific mineral particles hydrophilic (wettable) to suppress the attachment of bubbles on their surface to further enhance mineral separation. Flotation is generally a multistage process, particularly in complex ores containing several recoverable minerals. Some of the minerals floated in the first stage, or rougher (bulk) float, may subsequently be depressed in later flotation stages. Surface-active reagents called modifiers may be added to the slurry to affect the flotation response of the minerals. The development of flotation as an economic minerals beneficiation process has allowed the mining of previously uneconomic complex and low-grade ores. Flotation is used to obtain more than one-third of U.S. mineral concentrates, and its importance to minerals processing has been ranked with that of the development of smelting.

Every 5 years the Bureau of Mines conducts a survey of domestic mineral processing plants that employ froth flotation. The survey requests operational data on capacity, recovery rates, ore and concentrate grades, and consumption of utilities as well as consumption of reagents. Data received from the plants surveyed indicated that in 1985 more than 422 million short tons of ore and raw coal was processed by froth flotation to produce over 80 million tons of mineral concentrates. This required almost 8 billion kilowatt-hours of electricity, 947 billion gallons of water, and 1.4 billion pounds of chemical reagents. Of particular significance is the overall decline, since 1980, in the number, capacity, throughput, and reagent consumption of domestic flotation plants, particularly those processing copper, lead, and zinc sulfide ores.

The 1985 flotation survey has been modified from previous surveys to ensure greater accuracy in reporting and to obtain a more detailed breakdown of reagent consumption. Therefore, some of the data may not directly correlate with that of the previous data shown in tables 23-27. The following list describes some of the assumptions made in the 1985 survey and some of the factors that distinguished it from previous surveys.

1. In previous surveys, estimates were made to account for nearly all nonreporting companies, with the exception of coal processing plants and small precious metal producers. Estimates were not made for all of the nonrespondents to the 1985 survey owing to insufficient information, particularly for plants that processed only part of their production by flotation, most notably, those processing industrial mineral (nonmetallic) ores.

2. The 1985 survey differed from previous surveys in that reagents were listed and grouped by their chemical identity, rather than by the previous mixture of generic and trade names. In the 1985 survey, modifiers have been differentiated between pH regulators and dispersants. Other reagents have been classified according to the following definitions:[41]

*Collectors.*—Reagents used to render the surface of the mineral to be floated hydrophobic to improve the adherence of air bubbles to the mineral surface.

*Activators.*—Reagents that enhance collector adsorption, thereby promoting mineral flotation.

*Depressants.*—Reagents that reduce or inhibit the flotability of a mineral.

*Flocculants.*—Reagents that cause aggregation of small mineral particles into larger clusters.

*Frothers.*—Reagents used to promote a froth of sufficient stability or permanence, principally by reducing surface tension, that is adequate to permit removal of mineral-carrying bubbles.

3. Reported data on consumption of water, energy, and grinding media pertained to all operations inherent in the minerals processing plant; they were not limited to the flotation section of the plant and may include data on other separation or classification processes, such as gravity or magnetic separations. Energy consumption data were not reported for some ore types processed by flotation.

4. In past surveys, reagents used in effluent treatment were excluded from the tabulations of flotation reagents if reported separately. The 1985 survey specifically included effluent treatment chemicals; these have been tabulated separately.

5. Operating data have been presented on an annualized basis. Where plant capacity was reported on an hourly or daily basis, annual capacity was estimated using general plant practice for the type of ore being treated. For example, sulfide flotation plants were assumed to operate 350 days per year, 3 shifts per day, while coal preparation plants were assumed to operate 2 shifts per day, 250 days per year.

6. In previous surveys, reagent consumption was reported per ton of material processed by flotation, and total consumption was calculated from plant throughput. The 1985 survey canvassed the total consumption of reagent plus the quantity of reagent per ton of ore passing through that part of the circuit, as shown in tables 27-38.

Data for the 1985 flotation survey were received from 171 flotation plants. Data for eight more plants were estimated from past flotation surveys and from production data reported on other Bureau of Mines surveys. An additional 55 flotation plants surveyed were determined to be inactive, and 161 other plants failed to respond to the survey. Owing to insufficient data on their operating status or production of concentrates from froth flotation, no estimates were made for these nonreporting plants. However, it was estimated that 140 of the nonreporting plants were coal preparation plants, 8 were small gold or silver producers, 4 were metallic carbonate plants, and

9 were industrial mineral plants.

### DATA COVERAGE

**Sulfide Plants.**—Consumption data for the five base metal sulfide ore nonrespondents, comprising 14% of the ore treated in 1985 shown in table 23, were estimated from past flotation survey reports and 1985 mine production data reported to the Bureau of Mines. Data for the gold and silver properties that did not report were not estimated owing to their relatively small size and uncertain operational status.

**Metallic Carbonate Plants.**—Owing to insufficient data, no estimates were made for the metallic carbonate plants that did not respond to the survey. Reporting companies accounted for 100% of the data shown in table 24.

**Industrial Mineral Plants.**—Of the 12 industrial mineral plants that did not respond to the survey, estimates for consumption data were made for the 2 feldspar-quartz-mica plants and 1 potash plant, representing less than 1% of the ore treated shown in table 25. Owing to insufficient data, estimates were not made for two nonreporting kyanite plants nor for nonreporting glass sand plants. The data shown in table 35 for glass sand may account for as little as 55% of glass sand processed by flotation.

**Coal Preparation Plants.**—No attempt was made to estimate data for nonreporting coal preparation plants, many of which were probably not operating, operating intermittently, or no longer using froth flotation.

## RESEARCH AND TECHNOLOGY

The economic pressures of the international marketplace have forced innovative improvements in existing froth flotation and other minerals beneficiation technology and have prompted the development of revolutionary new methods. Two new concepts currently being transferred to industrial-scale operations are (1) control of the electrochemical environment of the slurry, and (2) control of bubble size in column flotation.

Froth flotation makes use of differences in the chemical properties of the surface of finely ground minerals to obtain separation. Bureau of Mines research has shown that changing the electrochemical potential of many sulfide minerals can be used to control their surface properties and, thus, their flotation response.[42] The principal reason for this is that the surface chemical reactions between collectors (such as xanthate) and most sulfide minerals are electrochemical processes. Furthermore, the electrochemical potential regions where the individual minerals float are sufficiently distinct to suggest that precise control of the electrochemical potential could be used to selectively separate the valuable minerals. This would substantially reduce the need for chemical modifiers such as cyanide and the need for pH control reagents, such as lime. Consequently, the chemical accumulation that complicates downstream stages of a multistage flowsheet would be reduced, and significant savings in flotation reagent costs would be realized.

The projected savings in reagent costs are the primary incentive for industry interest in electrochemical flotation technology. A typical copper flotation mill could anticipate savings on the order of $1 million annually by eliminating pH control reagents in pyrite-copper mineral separations, for example. Other benefits include increased revenues from higher recoveries that result from improved selectivity, and lower operating costs that result from simpler flowsheets and fewer chemicals.

In principle, electrochemical control is already being utilized in mill practice for the separation of copper from molybdenum by using the reducing agent sodium hydrosulfide to adjust the electrochemical potential of the copper minerals to below the flotation threshold. However, hydrosulfide losses due to oxidation have led to excessive hydrosulfide consumption. Consequently, some mills have gone to the expense of using nitrogen-purged flotation cells to reduce oxidative losses.

Column flotation cells are becoming more widely used in flotation mills.[43] Column cells do not use mechanical agitation to suspend particles and disperse air. They are tall columns that can be considered as having two distinct regions separated by the ore feed port situated about two-thirds of the way up the column. The interaction of downflowing ore particles and the rising air bubbles below the feed port in the lower collection zone determine mineral recovery. In the upper cleaning zone, product grade is determined (almost independently) by the rising mineral-laden froth and the downflowing washwater. Thus, a single column cell can substitute for several flotation stages, as is the case in some copper-molybdenum separations where single column flotation is achieving upgrading that previously required as many as seven stages of mechanical cells. Also, because air bubbles can be generated external to the column cell, column cells have the advantage of allowing for more efficient control of the bubble size. Bubble size is known to have an impact on metallurgical performance, especially on recovery of fine particles. Bubble generators and delivery tubes developed by the Bureau of Mines permit adjustment and control of bubble size from less than 0.1 millimeter up to 3 millimeters in diameter using a minimum quantity of frother. In addition, delivery tubes can be operated indefinitely without plugging and changed without interrupting operation when worn out. Increased utilization of column flotation cells should result in significant reductions in both capital and operating costs as well as in improved metallurgy.

For a number of years, improvements in beneficiation technology have been the result of evolutionary extensions of present practice. Where mill throughput was sufficiently large, the trend has continued toward larger grinding mills and flotation machines. Several years ago, the largest flotation machines were 1,350 cubic feet. Today, cells are available with a capacity of 2,500 cubic feet. Flotation circuits continue to be remodeled with fewer, but larger machines. Larger equipment reduces the number of units required, which helps lower maintenance costs, reduces floor space requirements, reduces energy costs, and simplifies computerized process control systems.

Introduction of angular spiral liners[44] for grate discharge ball mills is the most significant recent improvement in commercial grinding circuits. When placed in service at the San Manuel, AZ, concentrator of Magma Copper Co., grinding media consumption decreased by 19% and grinding energy consumption decreased by 16%. Similar savings were obtained after installation in Corporación Nacional de Cobre de Chile mills in Chile. These are substantial savings in the two highest cost areas of mineral beneficiation—energy and grinding media consumption. Further savings are resulting from a better understanding of the mechanisms of grinding media loss. Grinding media (balls, rods, and mill liners) are consumed through abrasion, corrosion, and fracture. Research[45] has shown that the relative contribution of each of these factors depends on the metallurgical properties of the media (usually steel), the type of ore being ground, and the grinding conditions (wet or dry). Abrasive wear is influenced by the rheological properties of the ore slurry and is the dominant wear mechanism for nonsulfide ores. For sulfide ores, electrochemical reactions between the sulfide mineral and the grinding steel increases the corrosive wear. The electrochemical reactions also dissolve metal ions into solutions, reducing the efficiency of subsequent flotation steps,[46] creating an environmental problem in effluent disposal, and affecting water recyclability. As a result, research into grinding media wear and the development of methods to reduce it are helping to reduce other production and environmental costs.

With respect to flotation mill size classification problems, screen classifiers are receiving attention as potential substitutes for cyclones in closed circuit grinding down to the 270-mesh level. Screen characteristics such as capacity, blinding avoidance, and screen cloth life have been improved, making them more cost effective. Vibrating screens up to 12 by 28 feet have been employed. Classification of grinding mill output with respect to mineral as well as particle size would help reduce overgrinding and energy consumption. Mineral-specific classification would enable the removal of a mineral as soon as it is liberated, whether or not it has been reduced to a particular size. Incorporation of a flotation cell into the grinder output just ahead of the hydrocyclone size classifier (flash flotation) is one method of mineral classification that is currently being evaluated on a commercial scale.

Automatic control is being applied to an increasing number of flotation concentrators.[47] However, fully automatic control using advanced computer technology has yet to be realized. Problems include lack of appropriate sensors and lack of a sufficiently detailed model of the processes being controlled. The most important sensor in a flotation control system at present is the on-stream X-ray analyzer, which provides chemical analysis of the metal content of process streams. Mineral content, the parameter needed for control, can only be inferred from these chemical data. The problem is particularly acute if the pulp consists of a complex mixture of sulfides. Based on elemental analysis alone, it is difficult to distinguish, for example, between chalcocite ($CuS_2$), cubanite ($CuFe_2S_3$), chalcopyrite ($CuFeS_2$), and pyrite ($FeS_2$). These minerals have very different flotation properties and require very different conditions for optimum flotation. Research continues to develop more comprehensive models of flotation systems and to identify new control parameters to more fully utilize the advanced process control technology available today. For example, the Comminution Generic Center at the University of Utah, sponsored by the Bureau of Mines, for example, is conducting research in particulate characterization by automated image analysis for the measurement and prediction of mineral liberation. If this technology can be adopted to on-line measurements, mineral content would be available as a control parameter.

The search for more selective reagents dominates industrial flotation research efforts.[46] The first comprehensive conference devoted exclusively to mineral processing reagents, "Reagents in the Minerals Industry," was held in Rome, Italy, in September 1984. The domestic minerals industry uses flotation reagents worth more than $180 million annually. However, custom designed reagents are generally made by chemical companies only for the larger deposits because of the costs of the research in comparison to the size of the market. Several new thio reagents have been claimed in the patent literature to be effective collectors for sulfide minerals. Furthermore, the reagent picture for sulfide minerals is likely to change substantially as electrochemical control becomes commercial practice. The need for oxidizing and reducing chemicals should increase, with a corresponding decrease in the need for custom designed collectors, modifiers, and pH controllers.

New developments in magnetic separation technology include higher fields, resulting from industrial utilization of superconducting magnets, and selective magnetic coatings. Present applications of magnetic separation include removal of contaminants in silica, quartz, feldspar and other oxide or industrial minerals, and improving the "whiteness" of particular clay minerals. Magnetic separation offers several potential advantages that include separation based on a bulk materials property instead of a highly variable surface property; better fine particle handling; no requirements for chemicals such as cyanide, avoiding contamination of products or effluents (a dispersant may be required for some applications); dry processing capability eliminating the need for water; and more facility for automation. Mineral processing flowsheets need to be reexamined for the potential use of this new magnetic separation technology.

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## Table 19.—Froth flotation plants operating in 1985, by type of ore and State[1]

| Type of ore and State | Number |
|---|---|
| Anthracite coal: Pennsylvania | 2 |
| Barite: | |
| Georgia | 1 |
| Nevada | 1 |
| Total | 2 |
| Bastnaesite: California | 1 |
| Bituminous coal: | |
| Alabama | 2 |
| Colorado | 1 |
| Illinois | 7 |
| Kentucky | 8 |
| Maryland | 1 |
| Missouri | 1 |
| Ohio | 3 |
| Pennsylvania | 11 |
| Utah | 1 |
| Virginia | 12 |
| West Virginia | 28 |
| Total | 75 |
| Borate: Nevada | 1 |
| Copper: | |
| Arizona | 3 |
| Idaho | 2 |
| Montana | 1 |
| New Mexico | 2 |
| Total | 8 |
| Copper-lead-zinc: Missouri | 3 |
| Copper-molybdenum: | |
| Arizona | 6 |
| Utah | 1 |
| Total | 7 |

See footnote at end of table.

**Table 19.—Froth flotation plants operating in 1985, by type of ore and State[1] —Continued**

| Type of ore and State | Number |
|---|---|
| Copper-zinc-iron: Tennessee | 1 |
| Feldspar-mica-quartz: | |
| Connecticut | 1 |
| Georgia | 1 |
| New Mexico | 1 |
| North Carolina | 7 |
| Total | 10 |
| Glass sand: | |
| California | 2 |
| Georgia | 1 |
| Louisiana | 1 |
| Michigan | 2 |
| Pennsylvania | 1 |
| Tennessee | 1 |
| Total | 8 |
| Gold: Nevada | 1 |
| Gold-silver: | |
| Idaho | 1 |
| Montana | 1 |
| Washington | 1 |
| Total | 3 |
| Iron: | |
| Michigan | 2 |
| Minnesota | 1 |
| Missouri | 1 |
| Total | 4 |
| Lead-zinc: | |
| Colorado | 2 |
| Idaho | 3 |
| Missouri | 2 |
| New York | 1 |
| Oregon | 1 |
| Total | 9 |
| Limestone-magnesite: | |
| Maryland | 1 |
| Nevada | 1 |
| Texas | 1 |
| Vermont | 1 |
| Total | 4 |
| Mercury: Nevada | 1 |
| Molybdenum: | |
| Colorado | 2 |
| Idaho | 1 |
| New Mexico | 1 |
| Total | 4 |
| Phosphate: | |
| Florida | 20 |
| North Carolina | 1 |
| Utah | 1 |
| Total | 22 |
| Potash: | |
| New Mexico | 4 |
| Utah | 1 |
| Total | 5 |
| Silver: Idaho | 1 |
| Talc: Alabama | 1 |
| Tungsten: California | 1 |
| Vermiculite: South Carolina | 1 |
| Zinc: Tennessee | 4 |
| Grand total | 179 |

[1] Includes only those plants responding to, or estimated for, by the Bureau of Mines.

## Table 20.—Flotation mill production and consumption in 1985

| Plants |  |  | Ore treated (thousand short tons) | Energy used (kilowatt-hours) |  | Water used[1] (gallons) |  | Rod consumption (pounds) |  | Ball consumption (pounds) |  | Steel liner consumption[2] (pounds per ton) | Flotation concentrates produced[3] (thousand short tons) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | Number | Capacity (thousand short tons) |  | Total (millions) | Per ton | Total (millions) | Per ton | Total (thousands) | Per ton[2] | Total (thousands) | Per ton[2] |  |  |
| Anthracite coal | 2 | W | W | W | W | W | W | -- | -- | -- | -- | -- | W |
| Barite | 2 | W | W | W | W | W | W | -- | -- | W | W | -- | W |
| Bastnaesite | 1 | W | W | W | W | W | W | -- | -- | W | W | -- | W |
| Bituminous coal | 75 | 36,114 | 27,666 | 399 | 6.5 | 38,886 | 326 | -- | -- | -- | -- | -- | 19,506 |
| Borate | 1 | W | W | W | W | W | W | -- | -- | -- | -- | -- | W |
| Copper | 8 | 56,135 | 68,815 | 1,051 | 15.3 | 47,687 | 693 | 7,402 | 0.385 | 90,015 | 1.308 | 0.092 | 2,771 |
| Copper-lead-zinc | 3 | W | W | W | W | W | W | W | W | W | W | W | W |
| Copper-molybdenum | 7 | 165,966 | 125,766 | 1,664 | 13.2 | 49,465 | 393 | 11,206 | .556 | 133,713 | 1.063 | .161 | 3,070 |
| Copper-zinc-iron | 1 | W | W | W | W | W | W | W | W | W | W | -- | W |
| Feldspar-mica-quartz | 10 | 2,920 | 2,084 | 83 | 44.5 | 10,856 | 4,429 | 2,709 | 1.159 | 160 | .257 | .200 | 1,899 |
| Glass sand | 8 | 4,467 | 2,774 | NA | NA | 5,593 | 1,464 | 341 | .324 | 265 | 1.104 | -- | 2,379 |
| Gold | 1 | W | W | W | W | W | W | -- | -- | W | W | -- | W |
| Gold-silver | 3 | 180 | 130 | 1 | 66 | 33 | 560 | -- | -- | 152 | 2.202 | .063 | 5 |
| Iron | 4 | 39,989 | 24,205 | 2,045 | 40.1 | 210,370 | 3,965 | 7,179 | .669 | 9,853 | .918 | .129 | 19,428 |
| Lead-zinc | 9 | 4,824 | 3,580 | 63 | 17.7 | 1,860 | 520 | 258 | .090 | 1,792 | .511 | .054 | 740 |
| Limestone-magnesite | 4 | 370 | 194 | NA | NA | 224 | 555 | 66 | .331 | 91 | .923 | -- | 238 |
| Mercury | 1 | W | W | W | W | W | W | -- | -- | W | W | W | W |
| Molybdenum | 4 | 36,923 | 24,054 | 255 | 16.0 | 7,066 | 294 | -- | -- | 27,701 | 1.736 | .221 | 67 |
| Phosphate | 22 | 160,087 | 120,687 | 1,849 | 11.3 | 565,852 | 3,164 | 304 | .008 | 540 | .491 | -- | 27,081 |
| Potash | 5 | 15,850 | 11,100 | 121 | 10.9 | 793 | 71 | 4 | .001 | 4 | .010 | -- | 1,668 |
| Silver | 1 | W | W | -- | -- | W | W | -- | -- | W | W | W | W |
| Talc | 1 | W | W | W | W | W | W | -- | -- | W | W | W | W |
| Tungsten | 1 | W | W | W | W | W | W | W | W | W | W | -- | W |
| Vermiculite | 1 | W | W | W | W | W | W | W | W | -- | -- | -- | W |
| Zinc | 4 | 5,655 | 3,310 | 34 | 13.4 | 1,233 | 581 | 212 | .214 | 545 | .132 | .010 | 186 |
| Total | 179 | 540,363 | 422,662 | 7,758 | XX | 947,856 | XX | 31,167 | XX | 269,154 | XX | XX | 80,100 |

NA Not available. W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.

[1] Includes new or makeup and reclaimed water.

[2] Weighted average only for company reporting this data.

[3] Excludes concentrates produced by other physical separation methods.

Table 21.—Consumption of reagents at flotation plants in 1985, by ore type

(Thousand pounds)

| Type of ore | Flotation reagents |  |  |  |  |  |  | Effluent treatment |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Collectors | De-pressants | Activators | pH regulators | Frothers | Flocculants | Dispersants | pH regulators | Flocculants | Filtering aids |
| Sulfides: |  |  |  |  |  |  |  |  |  |  |
| Copper | 2,231 | 5 | -- | 224,268 | 2,901 | 453 | -- | -- | 1,432 | 74 |
| Copper-lead-zinc | W | W | W | W | W | W | -- | -- | -- | W |
| Copper-molybdenum | 5,347 | 25,329 | 14,618 | 359,895 | 4,747 | 648 | 325 | 352 | 262 | 716 |
| Copper-zinc-iron | W | W | W | W | W | W | -- | W | W | -- |
| Gold | W | -- | -- | -- | W | -- | -- | -- | -- | W |
| Gold-silver | 4 | -- | -- | 94 | 1 | -- | -- | -- | -- | -- |
| Lead-zinc | 441 | 694 | 684 | 982 | 217 | 2 | -- | 2,875 | 102 | 246 |
| Mercury | 28 | -- | -- | -- | 18 | -- | -- | -- | -- | -- |
| Molybdenum | 12,861 | 1,046 | -- | 9,500 | 1,341 | -- | 32 | -- | -- | -- |
| Silver | W | W | -- | -- | W | W | -- | -- | -- | W |
| Zinc | 167 | -- | 1,371 | -- | 118 | 49 | -- | -- | -- | -- |
| Total[1] | 22,283 | 29,426 | 17,836 | 621,457 | 9,611 | 1,190 | 356 | 5,295 | 1,804 | 1,176 |
| Metallic carbonates and oxides: |  |  |  |  |  |  |  |  |  |  |
| Iron | 5,695 | 33,638 | 76 | 61,295 | 408 | 1,271 | 2,439 | 20,330 | 18,312 | 5,231 |
| Limestone-magnesite | 648 | 159 | -- | 6 | 25 | 76 | -- | -- | 5 | -- |
| Tungsten | 173 | -- | -- | 177 | -- | -- | 841 | 569 | 142 | -- |
| Total[1] | 6,515 | 33,798 | 76 | 61,477 | 433 | 1,347 | 3,280 | 20,898 | 18,460 | 5,231 |
| Industrial minerals: |  |  |  |  |  |  |  |  |  |  |
| Barite | W | W | -- | W | -- | -- | -- | -- | -- | -- |
| Bastnaesite | W | W | -- | W | -- | -- | -- | -- | -- | W |
| Borate | W | -- | -- | -- | -- | W | W | -- | -- | -- |
| Feldspar-mica-quartz | 2,758 | 560 | 599 | 2,540 | 169 | 384 | -- | 2,017 | 99 | -- |
| Glass sand | 3,469 | 20 | 36 | 3,807 | 22 | -- | 344 | 210 | 20 | -- |
| Phosphate | 327,065 | 2,114 | -- | 168,876 | 145 | 19 | 126 | 8,440 | 1,655 | -- |
| Potash | 3,874 | 1,732 | -- | 156 | 772 | 487 | -- | -- | -- | -- |
| Talc | -- | -- | -- | -- | W | W | -- | W | W | -- |
| Vermiculite | W | -- | -- | -- | W | W | -- | -- | -- | -- |
| Total[1] | 339,601 | 4,695 | 635 | 177,267 | 1,150 | 1,137 | 491 | 10,684 | 1,777 | -- |
| Anthracite and bituminous coal | 5,913 | -- | -- | 779 | 3,748 | 2,811 | -- | 1,023 | 1,823 | 1,647 |
| Grand total | 374,312 | 67,919 | 18,547 | 860,982 | 14,941 | 6,485 | 4,128 | 37,900 | 23,863 | 8,054 |

W Withheld to avoid disclosing respondent proprietary data; included in "Total" and "Grand total."

[1] Data may not add to totals shown because of independent rounding.

## Table 22.—Consumption, value, and function at flotation plants in 1985

| Function and name | Consumption: Total (thousand pounds) | Consumption: Pounds per ton |
|---|---|---|
| FLOTATION REAGENTS | | |
| Collectors: | | |
| Ethylxanthate | 1,833 | 0.041 |
| Amylxanthate | 741 | .014 |
| Isopropylxanthate | 702 | .013 |
| Isobutylxanthate | 123 | .006 |
| Unspecified xanthates | 224 | .006 |
| Alkyl dithiophosphate | 1,232 | .018 |
| Aryl dithiophosphate | 49 | .065 |
| Unspecified dithiophosphate | 64 | .024 |
| Xanthogen formate | 48 | .006 |
| Thionocarbamate | 952 | .017 |
| Mercaptobenzothiazole | 38 | .070 |
| Mixtures of thio reagents | 338 | .025 |
| Unspecified thio reagents | 26 | .003 |
| Primary amine | 885 | .177 |
| Secondary amine | 4,847 | .223 |
| Diamine | 241 | .027 |
| Unspecified amine | 5,418 | .718 |
| Amine derivative | 6,891 | .221 |
| Amine salt | 11,306 | .305 |
| Quarternary ammonium salt | 1,874 | .221 |
| Fatty and rosin acids and soaps | 156,373 | 1.385 |
| Fatty acid ester | 186 | .150 |
| Fatty acid derivative | 11,221 | .790 |
| Petroleum sulfonates | 500 | .309 |
| Petroleum derivative | 11,001 | .470 |
| Unspecified sulfide collector | 795 | .028 |
| Unspecified nonsulfide collectors | 90 | .057 |
| Phosphorus derivatives | 18 | .060 |
| Sulfates | 564 | 3.360 |
| Fuel oil | 145,783 | .544 |
| Kerosene | 9,341 | .131 |
| Other | 610 | .140 |
| Total pounds[1] | 374,312 | |
| Value | $75,361,184 | |
| Depressants: | | |
| Caustic soda | 24 | 2.000 |
| Hydrofluoric acid | 525 | 1.144 |
| Phosphorus pentasulfide | 2,816 | .190 |
| Cyanide salt | 3,890 | .318 |
| Sodium dichromate | 311 | .210 |
| Sulfide salt | 19,745 | 1.762 |
| Sodium silicate | 1,905 | .202 |
| Sodium silicofluoride | 239 | .940 |
| Zinc sulfate | 2,141 | .299 |
| Lignin derivative | 35 | .300 |
| Starches, celluloses, derivatives | 34,277 | 1.669 |
| Gums and dextrans | 1,732 | .208 |
| Synthetic polymer | 55 | .030 |
| Unspecified depressant | 101 | .023 |
| Other | 124 | 9.000 |
| Total pounds[1] | 67,919 | |
| Value | $14,725,536 | |
| pH regulators: | | |
| Hydrochloric acid | 156 | .059 |
| Sulfuric acid | 157,959 | 1.486 |
| Sulfur dioxide | 1,624 | .787 |
| Carbon dioxide | 14,846 | .830 |
| Caustic soda (NaOH) | 57,191 | 1.327 |
| Lime | 598,726 | 2,768 |
| Soda ash | 2,088 | 5.210 |
| Ammonia or ammonium hydroxide | 28,392 | .294 |
| Total pounds | 860,982 | |
| Value | $36,960,194 | |
| Frothers: | | |
| Aliphatic alcohol | 6,594 | .049 |
| Pine oil | 1,090 | .025 |
| Phenol | 777 | .036 |
| Polyglycol | 31 | .093 |

See footnote at end of table.

**Table 22.—Consumption, value, and function at flotation plants in 1985 —Continued**

| Function and name | Consumption | |
|---|---|---|
| | Total (thousand pounds) | Pounds per ton |
| FLOTATION REAGENTS —Continued | | |
| Frothers —Continued | | |
| Polyglycol ether | 1,679 | .029 |
| Unspecified polyol | 2,444 | .032 |
| Petroleum-based blends | 2,326 | 1.516 |
| Total pounds | 14,941 | |
| Value | $8,817,894 | |
| Flocculants: | | |
| Aluminum salts | 819 | .144 |
| Anionic polyacrylamide | 1,754 | .007 |
| Cationic polyacrylamide | 166 | .026 |
| Nonionic polyacrylamide | 224 | .006 |
| Unspecified polyacrylamide | 197 | .027 |
| Polyacrylate | 439 | .012 |
| Polyacrylonitrile | 486 | 2.499 |
| Polyethylene oxides | 21 | .001 |
| Unspecified polymer | 2,379 | .214 |
| Total pounds | 6,485 | |
| Value | $5,166,789 | |
| Activators: | | |
| Copper salt | 3,163 | .283 |
| Sodium sulfide or hydrosulfide | 14,673 | .662 |
| Hydrofluoric acid | 599 | .813 |
| Sodium hydroxide | 36 | .730 |
| Other | 76 | .023 |
| Total pounds | 18,547 | |
| Value | $8,171,890 | |
| Dispersants: | | |
| Sodium silicate | 3,204 | .099 |
| Polyphosphate | 924 | .028 |
| Total pounds | 4,128 | |
| Value | $1,059,555 | |
| Total reagents: | | |
| Pounds | 1,347,314 | |
| Value | $150,263,042 | |
| EFFLUENT TREATMENT REAGENTS | | |
| pH regulators: | | |
| Sulfuric acid | 9,879 | 4.181 |
| Caustic soda (NaOH) | 1,738 | 2,578 |
| Lime | 26,284 | 1.317 |
| Total pounds[1] | 37,900 | |
| Value | $2,244,760 | |
| Flocculants: | | |
| Aluminum salts | 7,486 | .416 |
| Starch-cellulose | 1 | .004 |
| Anionic polyacrylamide | 2,758 | .081 |
| Cationic polyacrylamide | 853 | .275 |
| Nonionic polyacrylamide | 9 | .195 |
| Unspecified polyacrylamide | 974 | .015 |
| Polyacrylate | 62 | .200 |
| Polyamide | 26 | .320 |
| Polyethyleneimines | 11 | .800 |
| Unspecified polymer | 11,739 | .161 |
| Total pounds[1] | 23,863 | |
| Value | $14,185,648 | |
| Dispersants: | | |
| Lignin sulfonate | 2,682 | 10.600 |
| Total pounds | 2,682 | |
| Value | $174,330 | |
| Total reagent: | | |
| Pounds | 64,445 | |
| Value | $16,604,738 | |

See footnote at end of table.

## Table 22.—Consumption, value, and function at flotation plants in 1985 —Continued

| Function and name | Consumption: Total (thousand pounds) | Consumption: Pounds per ton |
|---|---|---|
| OTHER REAGENTS | | |
| Filtering aids: | | |
| Nonionic surfactants | 6,391 | .199 |
| Polyacrylamides | 36 | .028 |
| Polyamines | 844 | .216 |
| Unspecified polymer | 782 | .270 |
| Total pounds[1] | 8,054 | |
| Value | $5,670,295 | |
| Grinding aids: | | |
| Sodium hexametaphosphate | 7 | .500 |
| Total pounds | 7 | |
| Value | $4,080 | |

[1] Data may not add to totals shown because of independent rounding.

## Table 23.—Froth flotation of sulfide ores

| | 1960 | 1965 | 1970 | 1975 | 1980 | 1985 |
|---|---|---|---|---|---|---|
| Operational data: | | | | | | |
| Number of plants | 95 | 108 | 105 | 86 | 71 | 42 |
| Capacity of plants[1] thousand short tons | 191,100 | 217,700 | 301,700 | 346,500 | 354,400 | 278,718 |
| Ore treated do | 155,100 | 200,800 | 281,700 | 278,400 | 279,900 | 233,100 |
| Concentrates produced do | 5,855 | 7,213 | 8,863 | 7,395 | 7,356 | 8,178 |
| Concentration factor | 26.5 | 27.8 | 31.8 | 37.6 | 38.1 | 28.5 |
| Reagent consumption: | | | | | | |
| Collectors thousand pounds | 25,346 | 23,988 | 32,133 | 27,972 | 38,704 | 22,288 |
| Depressants do | 6,338 | 10,863 | 17,061 | 33,313 | 51,433 | 29,426 |
| Activators do | 7,859 | 8,983 | 8,488 | 11,333 | 7,530 | 17,896 |
| Modifier:[2] | | | | | | |
| pH regulators in flotation do | NA | NA | NA | NA | NA | 621,457 |
| pH regulators in effluent treatment do | NA | NA | NA | NA | NA | 5,295 |
| Dispersants in flotation do | NA | NA | NA | NA | NA | 356 |
| Dispersants in effluent treatment do | NA | NA | NA | NA | NA | -- |
| Total do | 489,707 | 765,677 | 1,198,743 | 1,107,425 | 864,791 | 627,108 |
| Frothers do | 12,411 | 15,502 | 20,612 | 18,814 | 17,717 | 9,611 |
| Flocculants:[2] | | | | | | |
| In flotation do | 1,129 | 551 | 2,624 | 4,708 | 1,984 | 1,190 |
| In effluent treatment do | NA | NA | NA | NA | NA | 1,804 |
| Total do | 1,129 | 551 | 2,624 | 4,708 | 1,984 | 2,994 |
| Other reagent: Filtering aid do | NA | NA | NA | NA | NA | 1,176 |

NA Not available.

[1] Annual capacity for 1960-80 calculated from daily capacity assuming 350 operating days per year.

[2] Only the totals are available for historical data, which excludes effluent treatment.

## Table 24.—Froth flotation of metallic carbonate and oxide ores

| | 1960 | 1965 | 1970 | 1975 | 1980 | 1985 |
|---|---|---|---|---|---|---|
| Operational data: | | | | | | |
| Number of plants | 13 | 14 | 13 | 13 | 13 | 9 |
| Capacity of plants[1] thousand short tons | 4,900 | 6,800 | 22,750 | 31,500 | 52,850 | 41,059 |
| Ore treated do. | 2,854 | 16,079 | 22,213 | 30,149 | 42,903 | 24,490 |
| Concentrates produced do. | 941 | 7,086 | 13,040 | 15,582 | 24,049 | 19,670 |
| Concentration factor | 3.0 | 2.3 | 1.7 | 1.9 | 1.8 | 1.7 |
| Reagent consumption: | | | | | | |
| Collectors thousand pounds | 22,573 | 23,695 | 31,819 | 22,931 | 18,487 | 6,515 |
| Depressants do. | 610 | 1,588 | 2,627 | 18,226 | 30,393 | 33,798 |
| Activators do. | 1,280 | -- | -- | -- | -- | 76 |
| Modifier:[2] | | | | | | |
| pH regulators in flotation do. | NA | NA | NA | NA | NA | 61,477 |
| pH regulators in effluent treatment do. | NA | NA | NA | NA | NA | 20,898 |
| Dispersants in flotation do. | NA | NA | NA | NA | NA | 3,280 |
| Dispersants in effluent treatment do. | NA | NA | NA | NA | NA | -- |
| Total do. | 6,639 | 15,280 | 31,635 | 39,457 | [r]93,053 | 85,655 |
| Frothers do. | 1,345 | 865 | 164 | 397 | 808 | 433 |
| Flocculants:[2] | | | | | | |
| In flotation do. | 1,306 | 458 | 220 | 1,985 | [r]9,135 | 1,347 |
| In effluent treatment do. | NA | NA | NA | NA | NA | 18,460 |
| Total do. | 1,306 | 458 | 220 | 1,985 | [r]9,135 | 19,807 |
| Other reagents:[2] | | | | | | |
| Filtering aid do. | NA | NA | NA | NA | NA | 5,231 |
| Grinding aid do. | NA | NA | NA | NA | NA | 7 |

[r]Revised. NA Not available.

[1] Annual capacity for 1960-80 calculated from daily capacity assuming 350 operating days per year.

[2] Only the totals are available for historical data, which excludes effluent treatment.

## Table 25.—Froth flotation of industrial mineral ores

| | 1960 | 1965 | 1970 | 1975 | 1980 | 1985 |
|---|---|---|---|---|---|---|
| Operational data: | | | | | | |
| Number of plants | 55 | 64 | 56 | 75 | 75 | 51 |
| Capacity of plants[1] thousand short tons | 50,400 | 66,850 | 132,300 | 163,650 | 196,400 | 184,313 |
| Ore treated do. | 36,191 | 52,653 | 80,963 | 100,939 | 149,850 | 137,351 |
| Concentrates produced do. | 11,888 | 17,376 | 23,823 | 29,111 | 42,812 | 32,711 |
| Concentration factor | 3.0 | 3.0 | 3.4 | 3.5 | 3.5 | 4.2 |
| Reagent consumption: | | | | | | |
| Collectors[2] thousand pounds | 163,967 | 188,119 | 528,669 | 345,208 | 431,942 | 339,602 |
| Depressants do. | 9,231 | 4,346 | 11,023 | 7,314 | 11,719 | 4,695 |
| Activators do. | 2,988 | 511 | 484 | 393 | 1,122 | 635 |
| Modifier:[3] | | | | | | |
| pH regulators in flotation do. | NA | NA | NA | NA | NA | 177,267 |
| pH regulators in effluent treatment do. | NA | NA | NA | NA | NA | 10,684 |
| Dispersants in flotation do. | NA | NA | NA | NA | NA | 491 |
| Dispersants in effluent treatment do. | NA | NA | NA | NA | NA | 2,682 |
| Total do. | 82,456 | 54,889 | 161,470 | 112,639 | 116,819 | 191,124 |
| Frothers do. | 2,475 | 4,870 | 2,863 | 4,740 | 6,508 | 1,150 |
| Flocculants:[3] | | | | | | |
| In flotation do. | 875 | 3,207 | 751 | 2,477 | 2,614 | 1,137 |
| In effluent treatment do. | NA | NA | NA | NA | NA | 1,777 |
| Total do. | 875 | 3,207 | 751 | 2,477 | 2,614 | 2,914 |

NA Not available.

[1] Annual capacity for 1960-80 calculated from daily capacity assuming 350 operating days per year.

[2] Includes fuel oil used as an extender or activator.

[3] Only the totals are available for historical data, which excludes effluent treatment.

## Table 26.—Froth flotation of anthracite and bituminous coal

| | 1960 | 1965 | 1970 | 1975 | 1980 | 1985 |
|---|---|---|---|---|---|---|
| Operational data: | | | | | | |
| Number of plants | 81 | 69 | 66 | 78 | 80 | 77 |
| Capacity of plants[1] thousand short tons | 6,750 | 11,750 | 15,600 | 16,075 | 19,575 | 36,278 |
| Raw coal treated do. | 4,112 | 9,500 | 13,006 | 13,079 | 12,901 | 27,720 |
| Clean coal produced do. | 2,795 | 7,033 | 8,418 | 8,179 | 7,557 | 19,540 |
| Reagent consumption: | | | | | | |
| Collectors thousand pounds | 8,142 | 4,055 | 7,772 | 4,615 | 4,917 | 5,913 |
| Modifier:[2] | | | | | | |
| pH regulators in flotation do. | 1,609 | 298 | 2,716 | 298 | 26 | 779 |
| pH regulators in effluent treatment do. | NA | NA | NA | NA | NA | 1,023 |
| Total do. | 1,609 | 298 | 2,716 | 298 | 26 | 1,802 |
| Frothers do. | 585 | 1,555 | 2,564 | 2,668 | 3,044 | 3,748 |
| Flocculants:[2] | | | | | | |
| In flotation do. | 394 | 2,301 | 2,204 | 1,303 | 3,521 | 2,811 |
| In effluent treatment do. | NA | NA | NA | NA | NA | 1,823 |
| Total do. | 394 | 2,301 | 2,204 | 1,303 | 3,521 | 4,634 |
| Other reagent: Filtering aid do. | NA | NA | NA | NA | NA | 1,647 |

NA Not available.

[1] Annual capacity for 1960-80 calculated from daily capacity assuming 250 operating days per year.

[2] Effluent treatment not available for historical data.

## Table 27.—Froth flotation of copper in 1985

OPERATING DATA

| | | | |
|---|---|---|---|
| Plants: | | Energy used, kilowatt-hours: | |
| Number | 8 | Total millions | 1,051 |
| Design capacity[1] thousand short tons | 56,135 | Per ton | 15.3 |
| Ore treated:[1] | | Rod consumption, pounds: | |
| Quantity do. | 68,815 | Total thousands | 7,402 |
| Grade: | | Per ton[2] | 0.385 |
| Copper percent | 0.85 | Ball consumption, pounds: | |
| Gold troy ounce per ton | 0.001 | Total thousands | 90,015 |
| Silver do. | 0.326 | Per ton[2] | 1.308 |
| Water used, gallons: | | Liner consumption, pounds: | |
| Total millions | 47,687 | Steel total thousands | 3,706 |
| New or makeup do. | 12,627 | Per ton[2] | 0.092 |
| Reclaimed do. | 35,059 | Rubber total thousands | 48 |
| Per ton | 693 | Per ton[2] | 0.004 |

CONCENTRATES PRODUCED

| Type | Quantity (thousand short tons) | Grade (percent) | Recovery (percent) | Byproducts | | |
|---|---|---|---|---|---|---|
| | | | | Type | Grade (troy ounce per ton) | Recovery (percent) |
| Copper | 1,853 | 25.02 | 79 | Silver | 11.277 | 88 |
| | | | | Gold | .013 | 49 |

REAGENT CONSUMPTION

| Function and type | Total | | Per ton | |
|---|---|---|---|---|
| | Quantity (thousand pounds) | Value (thousands) | Quantity (pounds) | Value |
| Flotation reagents: | | | | |
| Collectors: | | | | |
| Ethylxanthate | 632 | $354 | 0.028 | $0.015 |
| Amylxanthate | 307 | 194 | .025 | .016 |
| Isopropylxanthate | 154 | 104 | .005 | .003 |
| Alkyl dithiophosphate | 629 | 546 | .015 | .013 |
| Thionocarbamate | 146 | 202 | .011 | .015 |
| Mixtures of thio reagents | 338 | 473 | .025 | .035 |
| Unspecified thio reagents | 26 | 18 | .003 | .002 |
| Total | 2,232 | 1,891 | XX | XX |
| Depressants: Cyanide salt | 5 | 4 | .014 | .012 |
| pH regulators: Lime | 224,268 | 10,667 | 3.397 | .162 |

See footnotes at end of table.

## Table 27.—Froth flotation of copper in 1985 —Continued

| Function and type | Total | | Per ton | |
|---|---|---|---|---|
| | Quantity (thousand pounds) | Value (thousands) | Quantity (pounds) | Value |
| **Flotation reagents —Continued** | | | | |
| **Frothers:** | | | | |
| Aliphatic alcohol | 1,044 | $650 | .037 | $0.023 |
| Pine oil | 271 | 116 | .021 | .009 |
| Polyglycol ether | 20 | 20 | .006 | .006 |
| Unspecified polyol | 1,566 | 834 | .041 | .022 |
| Total | 2,901 | 1,620 | XX | XX |
| **Flocculants:** | | | | |
| Aluminum salts | 155 | 22 | .055 | .008 |
| Anionic polyacrylamide | 74 | 46 | .026 | .016 |
| Nonionic polyacrylamide | 111 | 200 | .006 | .011 |
| Unspecified polymer | 113 | 65 | .036 | .021 |
| Total | 453 | 333 | XX | XX |
| **Effluent treatment:** | | | | |
| **Flocculants:** | | | | |
| Anionic polyacrylamide | 136 | 109 | .009 | .007 |
| Unspecified polyacrylamide | 694 | 386 | .024 | .013 |
| Unspecified polymer | 602 | 452 | .034 | .026 |
| Total | 1,432 | 947 | XX | XX |
| **Filtering aids:** Nonionic surfactants | 74 | 49 | .008 | .005 |

XX Not applicable.

[1] These values are for the flotation section only and would exclude material processed by other separation methods. Other operating data are for the entire plant (grinding mill and concentrator).

[2] Weighted average only for respondents reporting this data.

## Table 28.—Froth flotation of copper-molybdenum in 1985

OPERATING DATA

| | | | |
|---|---|---|---|
| **Plants:** | | **Energy used, kilowatt-hours:** | |
| Number | 7 | Total millions | 1,664 |
| Design capacity[1] thousand short tons | 165,966 | Per ton | 13.2 |
| **Ore treated:**[1] | | **Rod consumption, pounds:** | |
| Quantity do | 125,766 | Total thousands | 11,206 |
| Grade: | | Per ton[2] | 0.556 |
| Copper percent | 0.54 | **Ball consumption, pounds:** | |
| Molybdenum do | 0.05 | Total thousands | 133,713 |
| Gold troy ounce per ton | 0.002 | Per ton[2] | 1.063 |
| Silver do | 0.030 | **Liner consumption, pounds:** | |
| **Water used, gallons:** | | Steel total thousands | 16,388 |
| Total millions | 49,465 | Per ton[2] | 0.161 |
| New or makeup do | 20,728 | Rubber total thousands | 15 |
| Reclaimed do | 28,736 | Per ton[2] | 0.002 |
| Per ton | 393 | | |

CONCENTRATES PRODUCED

| Type | Quantity (thousand short tons) | Grade (percent) | Recovery (percent) | Byproducts | | |
|---|---|---|---|---|---|---|
| | | | | Type | Grade (troy ounce per ton) | Recovery (percent) |
| Copper | 2,052 | 27.46 | 83 | Gold | 0.054 | 62 |
| Molybdenum | 32 | 48.64 | 25 | Silver | 1.467 | 81 |

REAGENT CONSUMPTION

| Function and type | Total | | Per ton | |
|---|---|---|---|---|
| | Quantity (thousand pounds) | Value (thousands) | Quantity (pounds) | Value |
| **Flotation reagents:** | | | | |
| Collectors: | | | | |
| Ethylxanthate | 417 | $250 | 0.022 | $0.013 |
| Amylxanthate | 261 | 167 | .007 | .004 |
| Isopropylxanthate | 70 | 50 | .004 | .003 |
| Isobutylxanthate | 123 | 84 | .006 | .004 |
| Unspecified xanthates | 224 | 388 | .006 | .010 |

See footnotes at end of table.

## Table 28.—Froth flotation of copper-molybdenum in 1985 —Continued

| Function and type | Total | | Per ton | |
|---|---|---|---|---|
| | Quantity (thousand pounds) | Value (thousands) | Quantity (pounds) | Value |
| Flotation reagents —Continued | | | | |
| Collectors —Continued | | | | |
| Alkyl dithiophosphate | 405 | $352 | .021 | $0.018 |
| Unspecified dithiophosphate | 62 | 93 | .023 | .035 |
| Xanthogen formate | 48 | 80 | .006 | .010 |
| Thionocarbamate | 709 | 1,426 | .018 | .037 |
| Unspecified sulfide collector | 765 | 560 | .028 | .020 |
| Fuel oil | 2,207 | 442 | .037 | .007 |
| Kerosene | 55 | 10 | .003 | .001 |
| Total | 5,346 | 3,902 | XX | XX |
| Depressants: | | | | |
| Phosphorus pentasulfide | 1,926 | 573 | 1.068 | .318 |
| Cyanide salt | 3,652 | 1,543 | .680 | .287 |
| Sulfide salt | 19,649 | 3,587 | 6.874 | 1.255 |
| Sodium silicate | 102 | 20 | 1.720 | .344 |
| Total | 25,329 | 5,723 | XX | XX |
| Activators: Sodium sulfide or hydrosulfide | 14,613 | 6,576 | .677 | .305 |
| pH regulators: | | | | |
| Sulfuric acid | 2,263 | 7 | 7.040 | .021 |
| Caustic soda (NaOH) | 3 | 1 | .057 | .020 |
| Lime | 357,129 | 12,158 | 2.839 | .09 |
| Total | 359,395 | 12,166 | XX | XX |
| Frothers: | | | | |
| Aliphatic alcohol | 2,936 | 1,532 | .051 | .02 |
| Pine oil | 227 | 77 | .012 | .004 |
| Phenol | 777 | 505 | .036 | .023 |
| Polyglycol ether | 219 | 133 | .006 | .004 |
| Unspecified polyol | 587 | 232 | .021 | .008 |
| Total | 4,746 | 2,479 | XX | XX |
| Flocculants: | | | | |
| Anionic polyacrylamide | 157 | 110 | .006 | .004 |
| Nonionic polyacrylamide | 52 | 122 | .003 | .007 |
| Polyacrylate | 374 | 250 | .010 | .007 |
| Unspecified polymer | 66 | 58 | .113 | .099 |
| Total | 649 | 540 | XX | XX |
| Dispersants: | | | | |
| Sodium silicate | 51 | 10 | .160 | .032 |
| Polyphosphate | 273 | 169 | .016 | .010 |
| Total | 324 | 179 | XX | XX |
| Effluent treatment: pH regulators: Sulfuric acid | 352 | 1 | 1.056 | .003 |
| Flocculants: | | | | |
| Anionic polyacrylamide | 6 | 13 | .020 | .043 |
| Unspecified polyacrylamide | 211 | 183 | .011 | .009 |
| Unspecified polymer | 46 | 34 | .002 | .002 |
| Total | 263 | 230 | XX | XX |
| Filtering aids: | | | | |
| Nonionic surfactants | 701 | 513 | .700 | .512 |
| Unspecified polymer | 15 | 8 | .255 | .135 |
| Total | 716 | 521 | XX | XX |

XX Not applicable.

[1] These values are for the flotation section only and would exclude material processed by other separation methods. Other operating data are for the entire plant (grinding mill and concentrator).

[2] Weighted average only for respondents reporting this data.

## Table 29.—Froth flotation of lead-zinc in 1985

### OPERATING DATA

| | | | |
|---|---|---|---|
| **Plants:** | | **Energy used, kilowatt-hours:** | |
| Number | 9 | Total, millions | 63 |
| Design capacity[1], thousand short tons | 4,824 | Per ton | 17.7 |
| **Ore treated:**[1] | | **Rod consumption, pounds:** | |
| Quantity, do. | 3,580 | Total, thousands | 258 |
| Grade: | | Per ton[2] | 0.090 |
| Lead, percent | 5.87 | **Ball consumption, pounds:** | |
| Silver, troy ounce per ton | 1.976 | Total, thousands | 1,792 |
| Gold, do. | 0.059 | Per ton[2] | 0.511 |
| Zinc, percent | 3.34 | **Liner consumption, pounds:** | |
| **Water used, gallons:** | | Steel total, thousands | 152 |
| Total, millions | 1,860 | Per ton[2] | 0.054 |
| New or makeup, do. | 1,602 | Rubber total, thousands | 17 |
| Reclaimed, do. | 257 | Per ton[2] | 0.170 |
| Per ton | 520 | | |

### CONCENTRATES PRODUCED

| Type | Quantity (thousand short tons) | Grade (percent) | Recovery (percent) | Byproducts: Type | Byproducts: Grade (percent or troy ounce per ton) | Byproducts: Recovery (percent) |
|---|---|---|---|---|---|---|
| Lead | 271 | 74.21 | 96 | Silver | 20.700 | 78 |
| | | | | Zinc | 5.18 | 4 |
| | | | | Gold | 1.065 | 78 |
| | | | | Copper | 1.30 | 62 |
| Zinc | 188 | 55.28 | 90 | Gold | .073 | 10 |
| | | | | Silver | 2.330 | 3 |
| | | | | Lead | 9.75 | 8 |
| | | | | Copper | 1.20 | 18 |

### REAGENT CONSUMPTION

| Function and type | Total: Quantity (thousand pounds) | Total: Value (thousands) | Per ton: Quantity (pounds) | Per ton: Value |
|---|---|---|---|---|
| **Flotation reagents:** | | | | |
| **Collectors:** | | | | |
| Ethylxanthate | 123 | $96 | 0.137 | $0.107 |
| Amylxanthate | 6 | 7 | .900 | 1.017 |
| Isopropylxanthate | 219 | 136 | .082 | .051 |
| Alkyl dithiophosphate | 47 | 39 | .080 | .067 |
| Aryl dithiophosphate | 17 | 27 | .046 | .074 |
| Thionocarbamate | 1 | 1 | .100 | .200 |
| Unspecified sulfide collector | 29 | 25 | .095 | .082 |
| Total | 442 | 331 | XX | XX |
| **Depressants:** | | | | |
| Cyanide salt | 86 | 73 | .027 | .023 |
| Zinc sulfate | 607 | 180 | .215 | .064 |
| Total | 693 | 253 | XX | XX |
| **Activators:** | | | | |
| Copper salt | 624 | 370 | .185 | .110 |
| Sodium sulfide or hydrosulfide | 60 | 15 | .102 | .026 |
| Total | 684 | 385 | XX | XX |
| **pH regulators:** | | | | |
| Lime | 934 | 35 | .367 | .014 |
| Soda ash | 47 | 5 | .906 | .091 |
| Total | 981 | 40 | XX | XX |
| **Frothers:** | | | | |
| Aliphatic alcohol | 199 | 119 | .058 | .035 |
| Polyglycol ether | 17 | 14 | .053 | 1.761 |
| Petroleum-based blends | 1 | 1 | .020 | .013 |
| Total | 217 | 134 | XX | XX |
| **Flocculants:** | | | | |
| Anionic polyacrylamide | 1 | 1 | .100 | .102 |
| Nonionic polyacrylamide | 1 | 3 | .011 | .027 |
| Total | 2 | 4 | XX | XX |

See footnotes at end of table.

## Table 29.—Froth flotation of lead-zinc in 1985 —Continued

| Function and type | Total: Quantity (thousand pounds) | Total: Value (thousands) | Per ton: Quantity (pounds) | Per ton: Value |
|---|---|---|---|---|
| **Effluent treatment:** | | | | |
| pH regulators: | | | | |
| Sulfuric acid | 108 | $3 | .500 | $0.016 |
| Lime | 2,767 | 106 | 2.582 | .099 |
| Total | 2,875 | 109 | XX | XX |
| Flocculants: | | | | |
| Anionic polyacrylamide | 101 | 78 | .315 | .242 |
| Unspecified polyacrylamide | 1 | 2 | .009 | .025 |
| Total | 102 | 80 | XX | XX |
| Filtering aids: | | | | |
| Nonionic surfactants | 246 | 130 | .108 | .057 |
| Polyacrylamides | -- | -- | .001 | .001 |
| Total | 246 | 130 | XX | XX |

XX Not applicable.

[1] These values are for the flotation section only and would exclude material processed by other separation methods. Other operating data are for the entire plant (grinding mill and concentrator).

[2] Weighted average only for respondents reporting this data.

## Table 30.—Froth flotation of molybdenum in 1985

OPERATING DATA

| | | | |
|---|---|---|---|
| Plants: | | Energy used, kilowatt-hours: | |
| Number | 4 | Total millions | 255 |
| Design capacity[1] thousand short tons | 36,923 | Per ton | 16.0 |
| Ore treated:[1] | | Ball consumption, pounds: | |
| Quantity do. | 24,054 | Total thousands | 27,701 |
| | | Per ton[2] | 1.736 |
| Grade: Molybdenum percent | 0.20 | Steel liner consumption, pounds: | |
| Water used, gallons: | | Total thousands | 5,320 |
| Total millions | 7,066 | Per ton[2] | 0.221 |
| New or makeup do. | 2,847 | | |
| Reclaimed do. | 4,219 | | |
| Per ton | 294 | | |

CONCENTRATES PRODUCED

| Type | Quantity (thousand short tons) | Grade (percent) | Recovery (percent) |
|---|---|---|---|
| Molybdenum | 67 | 61.73 | 85 |

REAGENT CONSUMPTION

| Function and type | Total: Quantity (thousand pounds) | Total: Value (thousands) | Per ton: Quantity (pounds) | Per ton: Value |
|---|---|---|---|---|
| Flotation reagents: | | | | |
| Collectors: | | | | |
| Petroleum derivative | 9,397 | $8,457 | .811 | .730 |
| Fuel oil | 2,854 | 319 | .228 | .026 |
| Other | 610 | 73 | .140 | .017 |
| Total | 12,861 | 8,849 | XX | XX |
| Depressants: | | | | |
| Phosphorus pentasulfide | 890 | 450 | .068 | .035 |
| Cyanide salt | 15 | 13 | .050 | .044 |
| Sulfide salt | 41 | 8 | .005 | .001 |
| Unspecified depressant | 101 | 105 | .023 | .024 |
| Total | 1,047 | 576 | XX | XX |

See footnotes at end of table.

## Table 30.—Froth flotation of molybdenum in 1985 —Continued

| Function and type | Total: Quantity (thousand pounds) | Total: Value (thousands) | Per ton: Quantity (pounds) | Per ton: Value |
|---|---|---|---|---|
| **Flotation reagents —Continued** | | | | |
| pH regulators: | | | | |
| Caustic soda (NaOH) | 1,500 | $135 | .270 | $0.024 |
| Lime | 8,000 | 367 | .443 | .020 |
| Total | 9,500 | 502 | XX | XX |
| Frothers: | | | | |
| Aliphatic alcohol | 563 | 314 | .045 | .025 |
| Pine oil | 488 | 190 | .048 | .019 |
| Polyglycol ether | 210 | 193 | .036 | .033 |
| Unspecified polyol | 80 | 32 | .019 | .007 |
| Total | 1,341 | 729 | XX | XX |
| Dispersants: Sodium silicate | 32 | 6 | .516 | .108 |

XX Not applicable.

[1] These values are for the flotation section only and would exclude material processed by other separation methods. Other operating data are for the entire plant (grinding mill and concentrator).

[2] Weighted average only for respondents reporting this data.

## Table 31.—Froth flotation of zinc in 1985

OPERATING DATA

| | | | |
|---|---|---|---|
| Plants: | | Energy used, kilowatt-hours: | |
| Number | 4 | Total millions | 34 |
| Design capacity[1] thousand short tons | 5,655 | Per ton | 13.4 |
| Ore treated:[1] | | Rod consumption, pounds: | |
| Quantity do | 3,310 | Total thousands | 212 |
| | | Per ton[2] | 0.214 |
| Grade: Zinc percent | 3.8 | Ball consumption, pounds: | |
| Water used, gallons: | | Total thousands | 545 |
| Total millions | 1,233 | Per ton[2] | 0.132 |
| New or makeup do | 77 | Steel liner consumption, pounds: | |
| Reclaimed do | 1,156 | Total thousands | 6 |
| Per ton | 581 | Per ton[2] | 0.010 |

CONCENTRATES PRODUCED

| Type | Quantity (thousand short tons) | Grade (percent) | Recovery (percent) |
|---|---|---|---|
| Zinc | 185 | 63.52 | 93 |

REAGENT CONSUMPTION

| Function and type | Total: Quantity (thousand pounds) | Total: Value (thousands) | Per ton: Quantity (pounds) | Per ton: Value |
|---|---|---|---|---|
| Flotation reagents: | | | | |
| Collectors: | | | | |
| Amylxanthate | 3 | $3 | 0.004 | $0.004 |
| Alkyl dithiophosphate | 126 | 105 | .047 | .039 |
| Mercaptobenzothiazole | 38 | 35 | .070 | .063 |
| Total | 167 | 143 | XX | XX |
| Activators: Copper salt | 1,371 | 509 | .614 | .228 |
| Frothers: Polyglycol ether | 118 | 99 | .052 | .043 |
| Flocculants: Nonionic polyacrylamide | 49 | 89 | .065 | .117 |

XX Not applicable.

[1] These values are for the flotation section only and would exclude material processed by other separation methods. Ore treated may have been previously upgraded by other concentration methods. Other operating data are for the entire plant (grinding mill and concentrator).

[2] Weighted average only for respondents reporting this data.

## Table 32.—Froth flotation of iron in 1985

OPERATING DATA

| | | | |
|---|---|---|---|
| Plants: | | Energy used, kilowatt-hours: | |
| Number | 4 | Total millions | 2,045 |
| Design capacity[1] thousand short tons | 39,989 | Per ton | 40.1 |
| Ore treated:[1] | | Rod consumption, pounds: | |
| Quantity do. | 24,205 | Total thousands | 7,179 |
| | | Per ton[2] | 0.669 |
| Grade: Iron percent | 56.21 | Ball consumption, pounds: | |
| Water used, gallons: | | Total thousands | 9,853 |
| Total millions | 210,370 | Per ton[2] | 0.918 |
| New or makeup do. | 14,406 | Liner consumption, pounds: | |
| Reclaimed do. | 195,963 | Steel total thousands | 6,865 |
| Per ton | 3,965 | Per ton[2] | 0.129 |
| | | Rubber total thousands | 10 |
| | | Per ton[2] | 0.005 |

CONCENTRATES PRODUCED

| Type | Quantity (thousand short tons) | Grade (percent) | Recovery (percent) |
|---|---|---|---|
| Iron | 19,428 | 66.23 | 95 |

REAGENT CONSUMPTION

| Function and type | Total: Quantity (thousand pounds) | Total: Value (thousands) | Per ton: Quantity (pounds) | Per ton: Value |
|---|---|---|---|---|
| Flotation reagents: | | | | |
| Collectors: | | | | |
| Diamine | 150 | $164 | 0.018 | $0.020 |
| Unspecified amine | 498 | 641 | .150 | .195 |
| Amine salt | 4,866 | 2,919 | .270 | .162 |
| Fatty acid ester | 186 | 279 | .150 | .225 |
| Total | 5,695 | 4,003 | XX | XX |
| Depressants: Starches, celluloses, derivatives | 33,638 | 6,728 | 1.870 | .374 |
| Activators: Acetic acid | 76 | 14 | .023 | .004 |
| pH regulators: | | | | |
| Carbon dioxide | 14,846 | 1,485 | .830 | .083 |
| Caustic soda (NaOH) | 46,449 | 4,180 | 2.590 | .233 |
| Total | 61,295 | 5,665 | XX | XX |
| Frothers: Aliphatic alcohol | 408 | 131 | .035 | .015 |
| Flocculants: | | | | |
| Anionic polyacrylamide | 151 | 121 | .001 | .001 |
| Polyethylene oxides | 21 | 17 | .001 | .001 |
| Unspecified polymer | 1,099 | 857 | .880 | .686 |
| Total | 1,271 | 995 | XX | XX |
| Dispersants: | | | | |
| Sodium silicate | 1,810 | 362 | .100 | .020 |
| Polyphosphate | 629 | 390 | .040 | .025 |
| Total | 2,439 | 752 | XX | XX |
| Effluent treatment: | | | | |
| pH regulators: Lime | 20,330 | 1,626 | 1.130 | .090 |
| Flocculants: | | | | |
| Aluminum salts | 7,294 | 1,021 | .410 | .057 |
| Unspecified polymer | 11,018 | 8,247 | .858 | .268 |
| Total | 18,312 | 9,268 | XX | XX |
| Filtering aids: Nonionic surfactants | 5,231 | 3,714 | .290 | .206 |

XX Not applicable.

[1] These values are for the flotation section only and would exclude material processed by other separation methods. Other operating data are for the entire plant (grinding mill and concentrator).

[2] Weighted average only for respondents reporting this data.

### Table 33.—Froth flotation of limestone-magnesite in 1985

OPERATING DATA

| | | | |
|---|---|---|---|
| **Plants:** | | Energy used, kilowatt-hours: | |
| Number | 4 | Total millions | 1 |
| Design capacity[1] thousand short tons | 370 | Per ton | 6.3 |
| Ore treated[1] do | 194 | Rod consumption, pounds: | |
| **Water used, gallons:** | | Total thousands | 66 |
| **Total** **millions** | 224 | Per ton[2] | 0.331 |
| **New or makeup** **do** | 3 | Ball consumption, pounds: | |
| **Reclaimed** **do** | 221 | Total thousands | 91 |
| Per ton | 555 | Per ton[2] | 0.923 |

CONCENTRATES PRODUCED

| Type | Quantity (thousand short tons) |
|---|---|
| Limestone-magnesite | 238 |

REAGENT CONSUMPTION

| Function and type | Total | | Per ton | |
|---|---|---|---|---|
| | Quantity (thousand pounds) | Value (thousands) | Quantity (pounds) | Value |
| **Flotation reagents:** | | | | |
| Collectors: | | | | |
| Amine derivative | 6 | $6 | 1.000 | $1.000 |
| Amine salt | 73 | 88 | .566 | .684 |
| Fatty and rosin acids and soaps | 4 | 4 | .500 | .397 |
| Fatty acid derivative | 188 | 55 | 2.120 | .615 |
| Fuel oil | 377 | 45 | 4.240 | .509 |
| Total | 648 | 198 | XX | XX |
| **Depressants:** | | | | |
| Sodium silicate | 35 | 3 | 2.600 | .216 |
| Other | 124 | 6 | 9.000 | .414 |
| Total | 159 | 9 | XX | XX |
| **pH regulators:** Sulfuric acid | 6 | -- | .700 | .028 |
| **Frothers:** | | | | |
| Pine oil | 25 | 14 | .330 | .185 |
| Polyglycol ether | ([3]) | ([3]) | .030 | .021 |
| Total | 25 | 14 | XX | XX |
| **Flocculants:** | | | | |
| Aluminum salts | 61 | 7 | 5.200 | .562 |
| Unspecified polymer | 16 | 17 | .700 | .749 |
| Total | 77 | 24 | XX | XX |
| **Effluent treatment:** | | | | |
| **Flocculants:** Polyacrylate | 5 | 14 | .070 | .186 |
| **Grinding aids:** Sodium hexametaphosphate | 7 | 4 | .500 | .300 |

XX Not applicable.

[1] These values are for the flotation section only and would exclude material processed by other separation methods. Other operating data are for the entire plant (grinding mill and concentrator).

[2] Weighted average only for respondents reporting this data.

[3] Less than 1/2 unit.

## Table 34.—Froth flotation of feldspar-mica-quartz in 1985

OPERATING DATA

| | | | |
|---|---|---|---|
| Plants: | | Rod consumption, pounds: | |
| Number | 10 | Total thousands | 2,709 |
| Design capacity[1] thousand short tons | 2,920 | Per ton[2] | 1.159 |
| Ore treated[1] do. | 2,084 | Ball consumption, pounds: | |
| Water used, gallons: | | Total thousands | 160 |
| Total millions | 10,356 | Per ton[2] | 0.257 |
| New or makeup do. | 2,033 | Liner consumption pounds: | |
| Reclaimed do. | 8,323 | Steel total thousands | 346 |
| Per ton | 4,429 | Per ton[2] | 0.200 |
| Engery used, kilowatt-hours: | | Rubber total thousands | 6 |
| Total millions | 83 | Per ton[2] | 0.011 |
| Per ton | 44.5 | | |

CONCENTRATES PRODUCED

| Type | Quantity (thousand short tons) |
|---|---|
| Quartz | 258 |
| Feldspar | 607 |
| Mica | 67 |
| Lithium dioxide | W |

REAGENT CONSUMPTION

| Function and type | Total: Quantity (thousand pounds) | Total: Value (thousands) | Per ton: Quantity (pounds) | Per ton: Value |
|---|---|---|---|---|
| Flotation reagents: | | | | |
| Collectors: | | | | |
| Unspecified amine | 125 | $117 | .483 | .454 |
| Amine salt | 287 | 252 | .333 | .292 |
| Fatty and rosin acids and soaps | 1,000 | 350 | 1.500 | .525 |
| Fatty acid derivative | 251 | 107 | .877 | .373 |
| Petroleum sulfonates | 210 | 133 | .234 | .148 |
| Fuel oil | 886 | 96 | .668 | .072 |
| Total | 2,759 | 1,055 | XX | XX |
| Depressants: | | | | |
| Hydrofluoric acid | 525 | 202 | 1.144 | .441 |
| Lignin derivative | 35 | 1 | .300 | .006 |
| Total | 560 | 203 | XX | XX |
| Activators: Hydrofluoric acid | 599 | 271 | .813 | .368 |
| pH regulators: | | | | |
| Sulfuric acid | 1,743 | 56 | 1.543 | .049 |
| Caustic soda (NaOH) | 797 | 91 | .598 | .068 |
| Total | 2,540 | 147 | XX | XX |
| Frothers: | | | | |
| Aliphatic alcohol | 40 | 21 | .101 | .055 |
| Pine oil | 39 | 24 | .037 | .022 |
| Polyglycol | 8 | 1 | .060 | .004 |
| Polyglycol ether | 35 | 25 | .095 | .067 |
| Petroleum-based blends | 48 | 34 | .334 | .237 |
| Total | 170 | 105 | XX | XX |
| Flocculants: | | | | |
| Aluminum salts | 351 | 10 | .140 | .004 |
| Unspecified polymer | 33 | 36 | .040 | .043 |
| Total | 384 | 46 | XX | XX |
| Effluent treatment: | | | | |
| pH regulators: | | | | |
| Caustic soda (NaOH) | 719 | 14 | 3.420 | .068 |
| Lime | 1,299 | 55 | 2.421 | .103 |
| Total | 2,018 | 69 | XX | XX |

See footnotes at end of table.

## Table 34.—Froth flotation of feldspar-mica-quartz in 1985 —Continued

| Function and type | Total: Quantity (thousand pounds) | Total: Value (thousands) | Per ton: Quantity (pounds) | Per ton: Value |
|---|---|---|---|---|
| **Effluent treatment —Continued** | | | | |
| **Flocculants:** | | | | |
| Unspecified polyacrylamide | 5 | $6 | 0.040 | $0.050 |
| Polyacrylate | 55 | 52 | .253 | .239 |
| Polyethyleneimines | 11 | 9 | .800 | .696 |
| Unspecified polymer | 29 | 38 | .009 | .012 |
| Total | 100 | 105 | XX | XX |

W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1] These values are for the flotation section only and would exclude material processed by other separation methods. Other operating data are for the entire plant (grinding mill and concentrator).

[2] Weighted average only for respondents reporting this data.

## Table 35.—Froth flotation of glass sand in 1985

### OPERATING DATA

| | | | |
|---|---|---|---|
| **Plants:** | | **Rod consumption, pounds:** | |
| Number | 8 | Total thousands | 341 |
| Design capacity[1] thousand short tons | 4,467 | Per ton | 0.324 |
| Ore treated[1] do | 2,774 | **Ball consumption, pounds:** | |
| **Water used, gallons:** | | Total thousands | 265 |
| Total millions | 5,593 | Per ton[2] | 1.104 |
| New or makeup do | 383 | | |
| Reclaimed do | 5,210 | | |
| Per ton | 1,464 | | |

### CONCENTRATES PRODUCED

| Type | Quantity (thousand short tons) |
|---|---|
| Glass sand | 2,379 |

### REAGENT CONSUMPTION

| Function and type | Total: Quantity (thousand pounds) | Total: Value (thousands) | Per ton: Quantity (pounds) | Per ton: Value |
|---|---|---|---|---|
| **Flotation reagents:** | | | | |
| Collectors: | | | | |
| Diamine | 91 | $76 | 0.140 | $0.116 |
| Fatty and rosin acids and soaps | 2,639 | 812 | 1.18 | .363 |
| Petroleum sulfonates | 143 | 35 | .420 | .104 |
| Petroleum derivative | 596 | 70 | .885 | .104 |
| Total | 3,469 | 993 | XX | XX |
| Depressants: Sodium silicate | 20 | -- | .100 | .001 |
| Activators: Sodium hydroxide | 36 | 3 | .730 | .068 |
| **pH regulators:** | | | | |
| Sulfuric acid | 1,922 | 95 | 2.465 | .122 |
| Caustic soda (NaOH) | 1,885 | 173 | 1.425 | .130 |
| Total | 3,807 | 268 | XX | XX |
| **Frothers:** | | | | |
| Pine oil | 4 | 2 | .007 | .004 |
| Polyglycol | 15 | 13 | .150 | .129 |
| Petroleum-based blends | 3 | 3 | 8.400 | 7.727 |
| Total | 22 | 18 | XX | XX |
| Dispersants: Sodium silicate | 344 | 24 | 3.440 | .237 |
| **Effluent treatment:** | | | | |
| pH regulators: Sulfuric acid | 210 | 7 | .563 | .018 |
| Flocculants: Unspecified polymer | 20 | 17 | 1.150 | .978 |

XX Not applicable.

[1] These values are for the flotation section only and would exclude material processed by other separation methods. Other operating data are for the entire plant (grinding mill and concentrator).

[2] Weighted average only for respondents reporting this data.

## Table 36.—Froth flotation of phosphate in 1985

OPERATING DATA

| | | | |
|---|---|---|---|
| Plants: | | Energy used, kilowatt-hours: | |
| Number | 22 | Total ... millions | 1,849 |
| Design capacity[1] ... thousand short tons | 160,087 | Per ton | 11.3 |
| Ore treated:[1] | | Rod consumption, pounds: | |
| Quantity ... do | 120,687 | Total ... thousands | 304 |
| Grade: | | Per ton[2] | 0.008 |
| $P_2O_5$ ... percent | 9.94 | Ball consumption, pounds: | |
| Water used, gallons: | | Total ... thousands | 540 |
| Total ... millions | 565,852 | Per ton[2] | 0.491 |
| New or makeup ... do | 58,487 | | |
| Reclaimed ... do | 507,364 | | |
| Per ton | 3,164 | | |

CONCENTRATES PRODUCED

| Type | Quantity (thousand short tons) | Grade (percent) | Recovery (percent) |
|---|---|---|---|
| $P_2O_5$ | 27,081 | 31.21 | 70 |

REAGENT CONSUMPTION

| Function and type | Total | | Per ton | |
|---|---|---|---|---|
| | Quantity (thousand pounds) | Value (thousands) | Quantity (pounds) | Value |
| Flotation reagents: | | | | |
| Collectors: | | | | |
| Secondary amine | 4,847 | $1,600 | 0.223 | $0.074 |
| Unspecified amine | 4,800 | 2,880 | 1.200 | .720 |
| Amine derivative | 6,885 | 2,444 | .221 | .078 |
| Amine salt | 6,080 | 2,356 | .337 | .131 |
| Quarternary ammonium salt | 1,644 | 553 | .319 | .107 |
| Fatty and rosin acids and soaps | 151,447 | 23,015 | 1.419 | .216 |
| Fatty acid derivative | 10,770 | 1,389 | .794 | .102 |
| Petroleum sulfonates | 110 | 50 | .300 | .135 |
| Petroleum derivative | 676 | 68 | .074 | .007 |
| Fuel oil[3] | 130,943 | 12,521 | 1.268 | .121 |
| Kerosene | 8,863 | 1,025 | .170 | .020 |
| Total | 275,410 | 47,950 | XX | XX |
| Depressants: | | | | |
| Sodium silicate | 1,740 | 139 | .190 | .015 |
| Starches, celluloses, derivatives | 374 | 52 | .350 | .049 |
| Total | 2,114 | 191 | XX | XX |
| pH regulators: | | | | |
| Sulfuric acid | 134,866 | 3,398 | 1.320 | .033 |
| Caustic soda (NaOH) | 5,649 | 455 | .526 | .042 |
| Ammonia or ammonium hydroxide | 28,362 | 2,626 | .294 | .027 |
| Total | 168,877 | 6,479 | XX | XX |
| Frothers: | | | | |
| Polyglycol ether | 82 | 41 | .019 | .009 |
| Unspecified polyol | 13 | 11 | .400 | .330 |
| Petroleum-based blends | 50 | 32 | .200 | .128 |
| Total | 145 | 84 | XX | XX |
| Flocculants: Anionic polyacrylamide | 19 | 17 | .003 | .003 |
| Dispersants: Sodium silicate | 126 | 19 | .009 | .001 |
| Effluent treatment: | | | | |
| pH regulators: Sulfuric acid | 8,440 | 228 | 7.910 | .214 |
| Flocculants: Anionic polyacrylamide | 1,655 | 2,188 | .742 | .981 |

XX Not applicable.

[1] These values are for the flotation section only and would exclude material processed by other separation methods. Other operating data are for the entire plant (grinding mill and concentrator).

[2] Weighted average only for respondents reporting this data.

[3] Includes fuel oil used as an extender or activator.

## Table 37.—Froth flotation of potash in 1985

OPERATING DATA

| | | | |
|---|---|---|---|
| **Plants:** | | **Water used, gallons:** | |
| Number | 5 | Total ........ millions | 793 |
| Design capacity[1] .. thousand short tons | 15,850 | New or makeup ........ do | 278 |
| **Ore treated:**[1] | | Reclaimed ........ do | 514 |
| Quantity ........ do | 11,100 | Per ton | 71 |
| | | **Energy used, kilowatt-hours:** | |
| Grade: $K_2O$ ........ percent | 11.30 | Total ........ millions | 121 |
| | | Per ton | 10.9 |

CONCENTRATES PRODUCED

| Type | Quantity (thousand short tons) | Grade (percent) | Recovery (percent) |
|---|---|---|---|
| $K_2O$ | 1,669 | 59.15 | 79 |

REAGENT CONSUMPTION

| Function and type | Total | | Per ton | |
|---|---|---|---|---|
| | Quantity (thousand pounds) | Value (thousands) | Quantity (pounds) | Value |
| **Flotation reagents:** | | | | |
| **Collectors:** | | | | |
| Primary amine | 675 | $454 | 0.138 | $0.093 |
| Quarternary ammonium salt | 230 | 83 | .069 | .025 |
| Fatty and rosin acids and soaps | 990 | 198 | .350 | .070 |
| Petroleum derivative | 26 | 10 | .060 | .024 |
| Fuel oil | 1,953 | 213 | .425 | .046 |
| Total | 3,874 | 958 | XX | XX |
| Depressants: Gums and dextrans | 1,732 | 332 | .208 | .040 |
| pH regulators: Hydrochloric acid | 156 | 6 | .059 | .002 |
| **Frothers:** | | | | |
| Aliphatic alcohol | 525 | 294 | .054 | .030 |
| Polyglycol ether | 1 | 1 | .002 | .002 |
| Petroleum-based blends | 246 | 39 | .112 | .018 |
| Total | 772 | 334 | XX | XX |
| **Flocculants:** | | | | |
| Anionic polyacrylamide | 46 | 42 | .008 | .007 |
| Unspecified polyacrylamide | 17 | 31 | .009 | .016 |
| Unspecified polymer | 424 | 215 | .192 | .097 |
| Total | 487 | 288 | XX | XX |

XX Not applicable.

[1] These values are for the flotation section only and would exclude material processed by other separation methods. Other operating data are for the entire plant (grinding mill and concentrator).

## Table 38.—Froth flotation of bituminous coal in 1985

OPERATING DATA

| | | | |
|---|---|---|---|
| Plants: | | Water used, gallons: | |
| Number | 75 | Total millions | 38,886 |
| Design capacity[1] thousand short tons | 36,114 | New or makeup do. | 4,095 |
| Raw coal treated do. | 27,666 | Reclaimed do. | 34,791 |
| Energy used, kilowatt-hours: | | Per ton | 326 |
| Total millions | 399 | | |
| Per ton | 6.5 | | |

CONCENTRATES PRODUCED

| Type | Quantity (thousand short tons) |
|---|---|
| Clean coal | 19,509 |

REAGENT CONSUMPTION

| Function and type | Total: Quantity (thousand pounds) | Total: Value (thousands) | Per ton: Quantity (pounds) | Per ton: Value |
|---|---|---|---|---|
| Flotation reagents: | | | | |
| Collectors: | | | | |
| Fatty acid derivative | 11 | $17 | 0.043 | $0.065 |
| Petroleum derivative | 306 | 249 | .191 | .155 |
| Unspecified nonsulfide collectors | 90 | 125 | .057 | .079 |
| Phosphorus derivatives | 18 | 3 | .060 | .009 |
| Fuel oil | 5,062 | 3,025 | .372 | .222 |
| Kerosene | 423 | 55 | .742 | .096 |
| Total | 5,910 | 3,474 | XX | XX |
| pH regulators: | | | | |
| Caustic soda (NaOH) | 738 | 63 | .526 | .045 |
| Lime | 11 | 1 | .014 | .001 |
| Ammonia or ammonium hydroxide | 30 | 7 | .640 | .154 |
| Total | 779 | 71 | XX | XX |
| Frothers: | | | | |
| Aliphatic alcohol | 688 | 671 | .127 | .12 |
| Polyglycol | 8 | 5 | .080 | .052 |
| Polyglycol ether | 906 | 674 | .233 | .173 |
| Unspecified polyol | 161 | 36 | .038 | .009 |
| Petroleum-based blends | 1,979 | 1,456 | .174 | .128 |
| Total | 3,742 | 2,842 | XX | XX |
| Flocculants: | | | | |
| Aluminum salts | 12 | 2 | .065 | .007 |
| Anionic polyacrylamide | 1,274 | 1,726 | .408 | .553 |
| Cationic polyacrylamide | 166 | 87 | .026 | .013 |
| Unspecified polyacrylamide | 180 | 146 | .033 | .027 |
| Polyacrylate | 63 | 54 | -- | -- |
| Polyacrylonitrile | 486 | 243 | 2.499 | 1.250 |
| Unspecified polymer | 628 | 502 | .204 | .163 |
| Total | 2,809 | 2,760 | XX | XX |
| Effluent treatment: | | | | |
| pH regulators: | | | | |
| Caustic soda (NaOH) | 1,019 | 128 | 3.040 | .382 |
| Lime | 5 | (2) | .019 | .001 |
| Total | 1,024 | 128 | XX | XX |
| Flocculants: | | | | |
| Starch-cellulose | 1 | 3 | .004 | .007 |
| Anionic polyacrylamide | 854 | 716 | .056 | .047 |
| Cationic polyacrylamide | 853 | 507 | .275 | .164 |
| Nonionic polyacrylamide | 9 | 5 | .195 | .107 |
| Unspecified polyacrylamide | 56 | 46 | .127 | .104 |
| Polyamide | 26 | 17 | .320 | .211 |
| Unspecified polymer | 24 | 24 | .109 | .108 |
| Total | 1,823 | 1,318 | XX | XX |

See footnotes at end of table.

### Table 38.—Froth flotation of bituminous coal in 1985 —Continued

| Function and type | Total | | Per ton | |
|---|---|---|---|---|
| | Quantity (thousand pounds) | Value (thousands) | Quantity (pounds) | Value |
| Filtering aids: | | | | |
| Polyacrylamides | 36 | $29 | 0.031 | $0.024 |
| Polyamines | 844 | 584 | .261 | .181 |
| Unspecified polymer | 767 | 559 | .270 | .197 |
| Total | 1,647 | 1,172 | XX | XX |

XX Not applicable.

[1] These values are for the flotation section only and would exclude material processed by other separation methods. Other operating data are for the entire plant (grinding mill and concentrator).

[2] Less than 1/2 unit.

# Statistical Summary

## By Sarah P. Guerrino[1]

This chapter summarizes data on crude nonfuel mineral production for the United States, its island possessions, and the Commonwealth of Puerto Rico. Included also are the tables that show the principal nonfuel mineral commodities exported from and imported into the United States and that compare world and U.S. mineral production. The detailed data from which these tables were derived are contained in the individual commodity chapters of Volume I and in the State chapters of Volume II of this edition of the Minerals Yearbook.

Although crude mineral production may be measured at any of several stages of extraction and processing, the stage of measurement used in this chapter is what is normally termed "mine output." It usually refers to minerals or ores in the form in which they are first extracted from the ground, but customarily includes the output from auxiliary processing at or near the mines.

Because of inadequacies in the statistics available, some series deviate from the foregoing definition. For copper, gold, lead, silver, tin, and zinc, the quantities are recorded on a mine basis (as the recoverable content of ore sold or treated). However, the values assigned to these quantities are based on the average selling price of refined metal, not the mine value. Mercury is measured as recovered metal and valued at the average New York price for the metal.

The weight or volume units shown are those customarily used in the particular industries producing the commodities. Values shown are in current dollars, with no adjustments made to compensate for changes in the purchasing power of the dollar.

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## Table 1.—Nonfuel mineral production[1] in the United States

| Mineral | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| **METALS** |  |  |  |  |  |  |
| Antimony ore and concentrate short tons, antimony content | 838 | W | 557 | W | W | W |
| Bauxite thousand metric tons, dried equivalent | 679 | $11,309 | 856 | $15,643 | 674 | $12,855 |
| Copper (recoverable content of ores, etc.) metric tons | 1,038,098 | 1,751,476 | [r]1,102,613 | [r]1,625,116 | 1,105,758 | 1,632,483 |
| Gold (recoverable content of ores, etc.) troy ounces | [r]2,002,526 | [r]849,071 | [r]2,084,615 | [r]751,838 | 2,475,436 | 786,345 |
| Iron ore, usable (excluding byproduct iron sinter) thousand long tons, gross weight | 44,295 | 1,938,496 | W | W | W | W |
| Iron oxide pigments, crude short tons | 41,875 | 2,427 | 53,017 | 2,819 | 46,585 | 2,826 |
| Lead (recoverable content of ores, etc.) metric tons | [r]449,295 | [r]214,745 | [r]322,677 | [r]181,745 | 413,955 | 174,008 |
| Manganiferous ore (5% to 35% Mn) short tons, gross weight | 33,523 | 216 | 88,423 | 860 | 19,882 | W |
| Mercury 76-pound flasks | 25,070 | W | 19,048 | W | 16,530 | W |
| Molybdenum (content of ore and concentrate) thousand pounds | 48,805 | 166,612 | 102,405 | 326,780 | 111,936 | 347,812 |
| Nickel (content of ore and concentrate) short tons | -- | -- | 14,540 | W | 6,127 | W |
| Silver (recoverable content of ores, etc.) thousand troy ounces | [r]43,431 | [r]496,850 | [r]44,592 | [r]368,006 | 39,357 | 241,740 |
| Tungsten ore and concentrate metric tons, contained W | 1,016 | 10,528 | 1,173 | 13,409 | 983 | 9,143 |
| Vanadium (recoverable in ore and concentrate) short tons | 2,171 | 30,675 | 1,617 | 24,551 | W | W |
| Zinc (recoverable content of ores, etc.) metric tons | 275,294 | 251,204 | 252,768 | 270,838 | 226,545 | 201,607 |
| Combined value of beryllium concentrates, magnesium chloride for magnesium metal, rare-earth metal concentrate, tin, titanium concentrate (ilmenite and rutile), zircon concentrate, and values indicated by symbol W | XX | 133,220 | XX | 2,427,624 | XX | 2,212,104 |
| Total | XX | [r]5,857,000 | XX | [r]6,004,000 | XX | 5,621,000 |
| **INDUSTRIAL MINERALS (EXCEPT FUELS)** |  |  |  |  |  |  |
| Abrasive stones[2] short tons | 1,101 | 482 | 1,290 | 602 | 1,157 | 515 |
| Asbestos metric tons | 69,906 | 27,866 | 57,422 | 24,238 | 57,457 | 20,485 |
| Barite thousand short tons | 754 | 29,203 | 775 | 25,445 | 739 | 21,501 |
| Boron minerals do | 1,303 | 439,181 | 1,367 | 456,687 | 1,269 | 404,775 |
| Bromine[e] thousand pounds | 370,000 | 91,000 | 385,000 | 95,000 | 320,000 | 80,000 |
| Calcium chloride short tons | W | W | [e]838,000 | [e]93,000 | W | W |
| Cement: |  |  |  |  |  |  |
| Masonry thousand short tons | 2,921 | 186,240 | 3,281 | 219,877 | 3,187 | 213,096 |
| Portland do | 67,183 | 3,315,690 | 74,376 | 3,810,446 | 74,250 | 3,817,335 |
| Clays do | 40,858 | 931,091 | [r]43,702 | [r]1,032,127 | 44,974 | 1,011,377 |
| Diatomite do | 619 | 114,279 | 627 | 120,926 | 635 | 127,030 |
| Feldspar short tons | 710,000 | 22,500 | 710,000 | 23,500 | 700,000 | 22,800 |
| Fluorspar do | [e]61,000 | [e]10,000 | [e]72,000 | W | 66,000 | W |
| Garnet (abrasive) do | 29,767 | 2,533 | 29,647 | [e]2,487 | 36,727 | 2,973 |
| Gem stones[e] | NA | 7,425 | NA | 7,450 | NA | 7,425 |
| Gypsum thousand short tons | 12,884 | 101,361 | 14,319 | 113,671 | 14,726 | 114,229 |
| Helium (Grade-A) million cubic feet | [3]1,299 | [3]45,465 | [r]1,642 | [r]61,575 | 1,865 | 69,938 |
| Lime thousand short tons | 14,867 | 757,611 | 15,922 | 811,183 | 15,690 | 809,000 |
| Magnesium compounds short tons | 618,227 | 182,495 | W | W | W | W |
| Mica (scrap) thousand short tons | 140 | 6,479 | 161 | 7,139 | 138 | 6,330 |
| Peat do | 725 | 18,667 | 814 | 19,907 | 882 | 21,892 |
| Perlite short tons | 474,000 | 15,664 | 498,000 | 16,638 | 507,000 | 17,160 |
| Phosphate rock thousand metric tons | 42,573 | 1,021,095 | 49,197 | 1,182,244 | 50,835 | 1,203,265 |
| Potassium salts ($K_2O$ equivalent) do | 1,513 | 220,800 | 1,639 | 241,800 | 1,266 | 178,400 |

See footnotes at end of table.

## Table 1.—Nonfuel mineral production[1] in the United States —Continued

| Mineral | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| INDUSTRIAL MINERALS (EXCEPT FUELS) —Continued | | | | | | |
| Pumice ---- thousand short tons -- | 449 | $4,486 | 502 | $4,929 | 508 | $4,553 |
| Salt ---------------- do ---- | 34,573 | 597,081 | 39,225 | 675,099 | 39,484 | 741,799 |
| Sand and gravel: | | | | | | |
| Construction ---------- do ---- | [e]655,100 | [e]1,935,000 | 773,900 | 2,244,000 | [e]800,100 | [e]2,438,000 |
| Industrial ----------- do ---- | 26,620 | 335,200 | 29,380 | 377,200 | 29,430 | 374,070 |
| Sodium sulfate (natural) ---- do ---- | 423 | 39,425 | 435 | 40,125 | 389 | 35,860 |
| Stone:[4] | | | | | | |
| Crushed ------------- do ---- | 861,600 | 3,327,000 | [e]956,000 | [e]3,755,600 | 1,000,800 | 4,053,000 |
| Dimension ------------ do ---- | 1,090 | 147,843 | [e]1,157 | [e]154,949 | 1,121 | 171,667 |
| Sulfur, Frasch process thousand metric tons -- | 4,111 | 414,210 | 5,001 | 546,106 | 4,678 | 573,570 |
| Talc and pyrophyllite thousand short tons -- | 1,066 | 20,280 | [r]1,127 | [r]23,167 | 1,269 | 29,188 |
| Tripoli ------------- short tons -- | 111,020 | 649 | 124,482 | 699 | W | W |
| Vermiculite -- thousand short tons -- | 282 | 27,170 | 315 | 31,500 | 314 | 32,400 |
| Combined value of aplite, asphalt (native), emery, graphite (1983-84), helium (crude), iodine, kyanite, lithium minerals, magnesite, marl (greensand), olivine, pyrites, sodium carbonate (natural), staurolite, wollastonite, and values indicated by symbol W -- | XX | 867,486 | XX | [r]937,900 | XX | 1,007,903 |
| Total ---------------- | XX | 15,263,000 | XX | [r]17,157,000 | XX | 17,612,000 |
| Grand total ------------ | XX | [r]21,120,000 | XX | [r]23,161,000 | XX | 23,232,000 |

[e]Estimated. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; included in "Combined value" figure. XX Not applicable.

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

[2] Grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.

[3] Excludes output in New Mexico; withheld to avoid disclosing company proprietary data; included with industrial minerals "Combined value" figure for 1983.

[4] Excludes abrasive stone and bituminous limestone and sandstone; all included elsewhere in table.

### Table 2.—Nonfuel minerals produced in the United States and principal producing States in 1985

| Mineral | Principal producing States, in order of quantity | Other producing States |
|---|---|---|
| Antimony ore and concentrate | Idaho. | |
| Aplite | Va. | |
| Asbestos | Calif. and Vt. | |
| Asphalt (native) | Tex. and Utah. | |
| Barite | Nev., Ga., Mo., Mont | Ill., Tenn., Wash. |
| Bauxite | Ark. and Ala. | |
| Beryllium concentrate | Utah and S. Dak. | |
| Boron minerals | Calif. | |
| Bromine | Ark. and Mich. | |
| Calcium chloride | Mich., Calif., Wash. | |
| Cement | Tex., Calif., Pa., Mich | All other States except Conn., Del., Mass., Minn., N.H., N.J., N.C., N. Dak., R.I., Vt. |
| Clays | Ga., Tex., N.C., Wyo | All other States except Alaska, Del., Hawaii, R.I., Vt., Wis. |
| Copper (mine) | Ariz., N. Mex., Utah, Mont | Calif., Colo., Idaho, Ill., Mich., Mo., Nev., Tenn. |
| Diatomite | Calif., Nev., Wash., Oreg. | |
| Emery | N.Y. | |
| Feldspar | N.C., Conn., Ga., Calif | Okla. and S. Dak. |
| Fluorspar | Ill., Nev., Tex. | |
| Garnet, abrasive | Idaho, Maine, N.Y. | |
| Gold (mine) | Nev., S. Dak., Calif., Mont | Alaska, Ariz., Colo., Idaho, Mich., N. Mex., Oreg., S.C., Utah, Wash. |
| Gypsum | Tex., Mich., Iowa, Okla | Ariz., Ark., Calif., Colo., Ind., Kans., La., Mont., Nev., N. Mex., N.Y., Ohio, S. Dak., Utah, Va., Wash., Wyo. |
| Helium | Kans., Tex., N. Mex. | |
| Iodine | Okla. and Mich. | |
| Iron ore | Minn., Mich., Mo., Tex | Calif., Colo., Mont., Nev. |
| Iron oxide pigments (crude) | Mich., Ga., Mo., Va. | |
| Kyanite | Va. and Ga. | |
| Lead (mine) | Mo., Idaho, Colo., N.Y | Ariz., Ill., Mont., Nev., N. Mex., Tenn. |
| Lime | Ohio, Ky., Mo., Pa | All other States except Alaska, Conn., Del., Ga., Kans., Maine, Miss., N.H., N.J., N. Mex., N.C., R.I., S.C., Vt. |
| Lithium minerals | N.C. and Nev. | |
| Magnesite | Nev. | |
| Magnesium chloride | Tex. | |
| Magnesium compounds | Mich., Calif., Utah, Del | Tex. |
| Manganiferous ore | S.C. | |
| Marl, greensand | N.J. and Del. | |
| Mercury | Nev. | |
| Mica (scrap) | N.C., N. Mex., S.C., Ga | Conn., Pa., S. Dak., Tex. |
| Molybdenum | Colo., Ariz., Idaho, N. Mex | Calif., Nev., Utah. |
| Nickel | Oreg. | |
| Olivine | N.C. and Wash. | |
| Peat | Mich., Fla., Ind., Ill | Calif., Colo., Ga., Iowa, Md., Mass., Minn., Mont., N.J., N.Y., N.C., N. Dak., Ohio, Pa., S.C., Wash., Wis. |
| Perlite | N. Mex., Calif., Ariz., Nev | Colo. and Idaho. |
| Phosphate rock | Fla., N.C., Idaho, Tenn | Mont. and Utah. |
| Potassium salts | N. Mex., Utah, Calif. | |
| Pumice | Oreg., N. Mex., Calif., Idaho | Ariz., Hawaii, Kans., Okla. |
| Pyrites, ore and concentrate | Tenn., Colo., Ariz. | |
| Rare-earth metal concentrate | Calif. and Fla. | |
| Salt | La., Tex., N.Y., Ohio | Ala., Calif., Kans., Mich., Nev., N. Mex., N. Dak., Okla., Utah, W. Va. |
| Sand and gravel: | | |
| Construction | Calif., Tex., Mich., Ariz | All other States. |
| Industrial | Ill., Mich., N.J., Calif | All other States except Alaska, Del., Hawaii, Iowa, Maine, N.H., N. Mex., N. Dak., Oreg., S. Dak., Vt., Wyo. |
| Silver (mine) | Idaho, Nev., Ariz., Mont | Alaska, Calif., Colo., Ill., Mich., Mo., N. Mex., N.Y., S.C., S. Dak., Tenn., Utah, Wash. |
| Sodium carbonate (natural) | Wyo. and Calif. | |
| Sodium sulfate (natural) | Calif., Tex., Utah. | |
| Staurolite | Fla. | |
| Stone: | | |
| Crushed | Tex., Fla., Pa., Ga | All other States except Del. |
| Dimension | Ind., Ga., Vt | All other States except Alaska, Del., Fla., Hawaii, Ky., La., Miss., Neb., Nev., N.J., N. Dak., R.I., W. Va., Wyo. |
| Sulfur (Frasch) | Tex. and La. | |
| Talc and pyrophyllite | Mont., Tex., Vt., N.Y | Ark., Calif., Ga., N.C., Oreg., Va. |
| Tin | Alaska and Colo. | |
| Titanium concentrate | Fla. | |
| Tripoli | Ill. and Okla. | |
| Tungsten ore and concentrate | Calif. and Colo. | |
| Vanadium | Idaho and Ark. | |
| Vermiculite | Mont., S.C., Va. | |
| Wollastonite | N.Y. | |
| Zinc (mine) | Tenn., Mo., N.Y., N.J | Colo., Idaho, Ill., Ky. |
| Zircon concentrate | Fla. | |

### Table 3.—Value of nonfuel mineral production in the United States and principal nonfuel minerals produced in 1985

| State | Value (thousands) | Rank | Percent of U.S. total | Principal minerals, in order of value |
|---|---|---|---|---|
| Alabama | $405,915 | 20 | 1.75 | Cement, stone (crushed), lime, sand and gravel (construction). |
| Alaska | 89,969 | 42 | .39 | Sand and gravel (construction), gold, stone (crushed), tin. |
| Arizona | 1,550,085 | 4 | 6.68 | Copper, sand and gravel (construction), cement, molybdenum. |
| Arkansas | 256,697 | 29 | 1.11 | Bromine, cement, stone (crushed), sand and gravel (construction). |
| California | 2,094,796 | 1 | 9.02 | Cement, sand and gravel (construction), boron minerals, stone (crushed). |
| Colorado | 408,178 | 19 | 1.76 | Molybdenum, cement, sand and gravel (construction), stone (crushed). |
| Connecticut | 72,386 | 43 | .31 | Stone (crushed), sand and gravel (construction), feldspar, sand and gravel (industrial). |
| Delaware | [1]4,029 | 50 | .02 | Magnesium compounds, sand and gravel (construction), marl. |
| Florida | 1,559,266 | 3 | 6.71 | Phosphate rock, stone (crushed), cement, sand and gravel (construction). |
| Georgia | 946,075 | 7 | 4.07 | Clays, stone (crushed), cement, stone (dimension). |
| Hawaii | 53,272 | 44 | .23 | Stone (crushed), cement, sand and gravel (construction), lime. |
| Idaho | 348,154 | 22 | 1.50 | Silver, phosphate rock, molybdenum, lead. |
| Illinois | 459,920 | 17 | 1.98 | Stone (crushed), cement, sand and gravel (construction), sand and gravel (industrial). |
| Indiana | 302,954 | 25 | 1.30 | Cement, stone (crushed), sand and gravel (construction), lime. |
| Iowa | 228,017 | 32 | .98 | Stone (crushed), cement, sand and gravel (construction), gypsum. |
| Kansas | 322,170 | 23 | 1.39 | Cement, salt, stone (crushed), helium (Grade-A). |
| Kentucky | 267,558 | 27 | 1.15 | Stone (crushed), lime, cement, sand and gravel (construction). |
| Louisiana | 522,268 | 15 | 2.25 | Sulfur (Frasch), salt, sand and gravel (construction), cement. |
| Maine | 41,108 | 46 | .18 | Sand and gravel (construction), cement, stone (crushed), garnet. |
| Maryland | 258,274 | 28 | 1.11 | Stone (crushed), cement, sand and gravel (construction), clays. |
| Massachusetts | 117,205 | 38 | .50 | Sand and gravel (construction), stone (crushed), stone (dimension), lime. |
| Michigan | 1,347,858 | 6 | 5.80 | Iron ore, cement, magnesium compounds, stone (crushed). |
| Minnesota | 1,547,958 | 5 | 6.66 | Iron ore, sand and gravel (construction), stone (crushed), sand and gravel (industrial). |
| Mississippi | 102,793 | 40 | .44 | Sand and gravel (construction), clays, cement, stone (crushed). |
| Missouri | 734,960 | 9 | 3.16 | Cement, stone (crushed), lead, lime. |
| Montana | 200,272 | 34 | .86 | Gold, sand and gravel (construction), silver, copper. |
| Nebraska | 99,970 | 41 | .43 | Cement, sand and gravel (construction), stone (crushed), clays. |
| Nevada | 630,883 | 12 | 2.72 | Gold, diatomite, cement, silver. |
| New Hampshire | 32,900 | 47 | .14 | Sand and gravel (construction), stone (dimension), stone (crushed), clays. |
| New Jersey | 177,576 | 35 | .76 | Stone (crushed), sand and gravel (construction), sand and gravel (industrial), zinc. |
| New Mexico | 656,889 | 11 | 2.83 | Copper, potassium salts, molybdenum, cement. |
| New York | 657,308 | 10 | 2.83 | Stone (crushed), cement, salt, sand and gravel (construction). |
| North Carolina | 432,756 | 18 | 1.86 | Stone (crushed), phosphate rock, lithium compounds, sand and gravel (construction). |
| North Dakota | 24,184 | 48 | .10 | Sand and gravel (construction), lime, salt, clays. |
| Ohio | 607,127 | 13 | 2.61 | Salt, stone (crushed), sand and gravel (construction), cement. |
| Oklahoma | 251,607 | 30 | 1.08 | Stone (crushed), cement, sand and gravel (construction), sand and gravel (industrial). |
| Oregon | 130,296 | 36 | .56 | Stone (crushed), sand and gravel (construction), cement, lime. |
| Pennsylvania | 804,474 | 8 | 3.46 | Stone (crushed), cement, lime, sand and gravel (construction). |
| Rhode Island | 12,192 | 49 | .05 | Stone (crushed), sand and gravel (construction), sand and gravel (industrial). |
| South Carolina | 275,929 | 26 | 1.19 | Cement, stone (crushed), clays, sand and gravel (industrial). |
| South Dakota | 207,339 | 33 | .89 | Gold, cement, stone (dimension), sand and gravel (construction). |
| Tennessee | 472,287 | 16 | 2.03 | Stone (crushed), zinc, cement, pyrites. |
| Texas | 1,733,359 | 2 | 7.46 | Cement, sulfur (Frasch), stone (crushed), sand and gravel (construction). |
| Utah | 312,359 | 24 | 1.34 | Cement, copper, gold, sand and gravel (construction). |
| Vermont | 49,854 | 45 | .21 | Stone (dimension), stone (crushed), sand and gravel (construction), talc. |
| Virginia | 381,276 | 21 | 1.64 | Stone (crushed), cement, sand and gravel (construction), lime. |
| Washington | 243,670 | 31 | 1.05 | Cement, sand and gravel (construction), gold, stone (crushed). |

See footnotes at end of table.

## Table 3.—Value of nonfuel mineral production in the United States and principal nonfuel minerals produced in 1985 —Continued

| State | Value (thousands) | Rank | Percent of U.S. total | Principal minerals, in order of value |
|---|---|---|---|---|
| West Virginia | $105,409 | 39 | .45 | Stone (crushed), cement, sand and gravel (industrial), salt. |
| Wisconsin | 125,110 | 37 | .54 | Stone (crushed), sand and gravel (construction), lime, sand and gravel (industrial). |
| Wyoming | 552,463 | 14 | 2.38 | Sodium carbonate, clays, cement (portland), sand and gravel (construction). |
| Total | 23,232,000 | XX | 100.00 | |

XX Not applicable.
[1]Incomplete total.

## Table 4.—Value of nonfuel mineral production per capita and per square mile in 1985, by State

| State | Area (square miles) | Population (thousands) | Value of mineral production | | | | |
|---|---|---|---|---|---|---|---|
| | | | Total (thousands) | Per square mile | | Per capita | |
| | | | | Dollars | Rank | Dollars | Rank |
| Alabama | 51,705 | 4,021 | $405,915 | 7,851 | 24 | 101 | 20 |
| Alaska | 591,004 | 521 | 89,969 | 152 | 50 | 173 | 10 |
| Arizona | 114,000 | 3,187 | 1,550,085 | 13,597 | 11 | 486 | 3 |
| Arkansas | 53,187 | 2,359 | 256,697 | 4,826 | 31 | 109 | 18 |
| California | 158,706 | 26,365 | 2,094,796 | 13,199 | 13 | 79 | 24 |
| Colorado | 104,091 | 3,231 | 408,178 | 3,921 | 35 | 126 | 16 |
| Connecticut | 5,018 | 3,174 | 72,386 | 14,425 | 9 | 23 | 47 |
| Delaware | 2,044 | 622 | [1]4,029 | 1,971 | 44 | 6 | 50 |
| Florida | 58,664 | 11,366 | 1,559,266 | 26,580 | 1 | 137 | 14 |
| Georgia | 58,910 | 5,976 | 946,075 | 16,060 | 7 | 158 | 11 |
| Hawaii | 6,471 | 1,054 | 53,272 | 8,232 | 21 | 51 | 37 |
| Idaho | 83,564 | 1,005 | 348,154 | 4,166 | 33 | 346 | 6 |
| Illinois | 56,345 | 11,535 | 459,920 | 8,163 | 23 | 40 | 39 |
| Indiana | 36,185 | 5,499 | 302,954 | 8,372 | 20 | 55 | 35 |
| Iowa | 56,275 | 2,884 | 228,017 | 4,052 | 34 | 79 | 25 |
| Kansas | 82,277 | 2,450 | 322,170 | 3,916 | 36 | 131 | 15 |
| Kentucky | 40,409 | 3,726 | 267,558 | 6,621 | 25 | 72 | 27 |
| Louisiana | 47,751 | 4,481 | 522,268 | 10,937 | 15 | 117 | 17 |
| Maine | 33,265 | 1,164 | 41,108 | 1,236 | 48 | 35 | 42 |
| Maryland | 10,460 | 4,392 | 258,274 | 24,692 | 2 | 59 | 32 |
| Massachusetts | 8,284 | 5,822 | 117,205 | 14,148 | 10 | 20 | 48 |
| Michigan | 58,527 | 9,088 | 1,347,853 | 23,030 | 3 | 148 | 12 |
| Minnesota | 84,402 | 4,193 | 1,547,958 | 18,340 | 5 | 369 | 5 |
| Mississippi | 47,689 | 2,613 | 102,793 | 2,155 | 43 | 39 | 40 |
| Missouri | 69,697 | 5,029 | 734,960 | 10,545 | 16 | 146 | 13 |
| Montana | 147,046 | 826 | 200,272 | 1,362 | 45 | 242 | 8 |
| Nebraska | 77,355 | 1,606 | 99,970 | 1,292 | 47 | 62 | 31 |
| Nevada | 110,561 | 936 | 630,883 | 5,706 | 27 | 674 | 2 |
| New Hampshire | 9,279 | 998 | 32,900 | 3,546 | 40 | 33 | 44 |
| New Jersey | 7,787 | 7,562 | 177,576 | 22,804 | 4 | 23 | 46 |
| New Mexico | 121,593 | 1,450 | 656,889 | 5,402 | 29 | 453 | 4 |
| New York | 49,108 | 17,783 | 657,308 | 13,385 | 12 | 37 | 41 |
| North Carolina | 52,669 | 6,255 | 432,756 | 8,217 | 22 | 69 | 28 |
| North Dakota | 70,703 | 685 | 24,184 | 342 | 49 | 35 | 43 |
| Ohio | 41,330 | 10,744 | 607,127 | 14,690 | 8 | 57 | 33 |
| Oklahoma | 69,956 | 3,301 | 251,607 | 3,597 | 38 | 76 | 26 |
| Oregon | 97,073 | 2,687 | 130,296 | 1,342 | 46 | 48 | 38 |
| Pennsylvania | 45,308 | 11,853 | 804,474 | 17,756 | 6 | 68 | 29 |
| Rhode Island | 1,212 | 968 | 12,192 | 10,059 | 17 | 13 | 49 |
| South Carolina | 31,113 | 3,347 | 275,929 | 8,869 | 19 | 82 | 23 |
| South Dakota | 77,116 | 708 | 207,339 | 2,689 | 41 | 293 | 7 |
| Tennessee | 42,144 | 4,762 | 472,287 | 11,207 | 14 | 99 | 21 |
| Texas | 266,807 | 16,370 | 1,733,359 | 6,497 | 26 | 106 | 19 |
| Utah | 84,899 | 1,645 | 312,359 | 3,679 | 37 | 190 | 9 |
| Vermont | 9,614 | 535 | 49,854 | 5,186 | 30 | 93 | 22 |
| Virginia | 40,767 | 5,706 | 381,276 | 9,353 | 18 | 67 | 30 |
| Washington | 68,138 | 4,409 | 243,670 | 3,576 | 39 | 55 | 34 |
| West Virginia | 24,231 | 1,936 | 105,409 | 4,350 | 32 | 54 | 36 |
| Wisconsin | 56,153 | 4,775 | 125,110 | 2,228 | 42 | 26 | 45 |
| Wyoming | 97,809 | 509 | 552,463 | 5,648 | 28 | 1,085 | 1 |
| Total[2] or average | 3,618,701 | 238,114 | 23,232,000 | 6,416 | XX | 98 | XX |

XX Not applicable.
[1]Incomplete total.
[2]Excludes Washington, DC (which has no mineral production), with an area of 69 square miles and a population of 626,000.

## Table 5.—Nonfuel mineral production[1] in the United States, by State

| Mineral | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| **ALABAMA** | | | | | | |
| Cement: | | | | | | |
| Masonry thousand short tons | 210 | $13,417 | 259 | $17,247 | 268 | $18,118 |
| Portland do. | 3,279 | 150,255 | 3,656 | 167,191 | 3,721 | 165,972 |
| Clays[2] do. | 1,863 | 20,758 | 1,906 | 30,500 | 1,878 | 13,139 |
| Gem stones | NA | 1 | NA | 1 | NA | 1 |
| Lime thousand short tons | 981 | 41,149 | 1,163 | 50,560 | 1,216 | 52,295 |
| Sand and gravel: | | | | | | |
| Construction do. | •8,600 | •23,500 | 10,348 | 26,188 | •11,000 | •32,000 |
| Industrial do. | 418 | 3,256 | 442 | 3,600 | 524 | 4,583 |
| Stone: | | | | | | |
| Crushed do. | 20,558 | 95,374 | •22,000 | •98,500 | 25,858 | 109,176 |
| Dimension do. | 7 | 2,661 | •8 | •2,674 | 11 | 2,881 |
| Combined value of bauxite, clays (bentonite), phosphate rock (1983), and salt | XX | 10,956 | XX | 13,880 | XX | 7,806 |
| Total | XX | 361,327 | XX | 409,841 | XX | 405,915 |
| **ALASKA** | | | | | | |
| Gem stones | NA | $60 | NA | $60 | NA | $60 |
| Gold (recoverable content of ores, etc.) troy ounces | 39,523 | 16,758 | $^{r}$19,433 | $^{r}$7,009 | 44,733 | 14,210 |
| Sand and gravel (construction) thousand short tons | •45,200 | •97,200 | 30,861 | 66,883 | •29,000 | •68,000 |
| Silver (recoverable content of ores, etc.) thousand troy ounces | 4 | 47 | $^{r}$(3) | $^{r}$1 | W | W |
| Stone (crushed) thousand short tons | 1,981 | 9,460 | •2,500 | •10,800 | 1,907 | 8,535 |
| Combined value of cement (portland, 1984-85), copper (1983), lead (1983), tin, and values indicated by symbol W | XX | 971 | XX | $^{r}$2,543 | XX | 4,164 |
| Total | XX | 124,496 | XX | $^{r}$87,296 | XX | 89,969 |
| **ARIZONA** | | | | | | |
| Clays thousand short tons | 151 | $1,425 | 188 | $819 | 186 | $1,503 |
| Copper (recoverable content of ores, etc.) metric tons | 678,216 | 1,144,285 | 746,458 | 1,100,182 | 796,556 | 1,175,995 |
| Gem stones | NA | 2,800 | NA | 2,700 | NA | 2,700 |
| Gold (recoverable content of ores, etc.) troy ounces | 61,991 | 26,284 | $^{r}$54,897 | $^{r}$19,799 | 52,053 | 16,535 |
| Gypsum thousand short tons | 265 | 1,929 | 261 | 2,332 | 251 | 1,926 |
| Lead (recoverable content of ores, etc.) metric tons | $^{r}$234 | $^{r}$112 | W | W | 581 | 244 |
| Lime thousand short tons | 340 | 16,700 | 359 | 17,304 | 476 | 21,226 |
| Molybdenum (content of concentrate) thousand pounds | 23,934 | 80,210 | 24,018 | 76,112 | 24,125 | 68,389 |
| Pumice thousand short tons | 2 | 15 | 2 | 21 | W | 2 |
| Sand and gravel (construction) do. | •23,200 | •75,000 | 30,439 | 101,959 | •37,000 | •118,000 |
| Silver (recoverable content of ores, etc.) thousand troy ounces | 4,492 | 51,383 | $^{r}$4,247 | $^{r}$34,570 | 4,885 | 30,007 |
| Stone: | | | | | | |
| Crushed thousand short tons | 4,755 | 24,079 | •5,200 | •27,300 | 5,929 | 23,111 |
| Dimension do. | (3) | 1 | •(3) | •(3) | W | W |
| Combined value of cement, perlite, pyrites, salt (1984), sand and gravel (industrial), tin (1984), and values indicated by symbol W | XX | 87,449 | XX | 102,839 | XX | 95,447 |
| Total | XX | $^{r}$1,511,672 | XX | $^{r}$1,485,987 | XX | 1,550,085 |
| **ARKANSAS** | | | | | | |
| Clays thousand short tons | 879 | $9,956 | 1,019 | $7,838 | 1,052 | $10,769 |
| Gem stones | NA | 200 | NA | 200 | NA | 200 |
| Sand and gravel: | | | | | | |
| Construction thousand short tons | •6,900 | •19,600 | 8,334 | 23,786 | •8,500 | •24,400 |
| Industrial do. | 886 | 4,796 | 459 | 6,207 | 412 | 5,414 |
| Stone: | | | | | | |
| Crushed do. | 13,448 | 51,267 | •15,200 | •59,300 | 14,815 | 60,874 |
| Dimension do. | 9 | 573 | -- | -- | 5 | 305 |
| Talc do. | 7 | 66 | W | W | W | W |
| Combined value of abrasives, bauxite, bromine, cement, gypsum, lime, tripoli (1983-84), vanadium (1984-85), and values indicated by symbol W | XX | 159,972 | XX | 174,797 | XX | 154,735 |
| Total | XX | 246,430 | XX | 272,628 | XX | 256,697 |

See footnotes at end of table.

## Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

| Mineral | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| **CALIFORNIA** | | | | | | |
| Boron minerals ___ thousand short tons__ | 1,303 | $439,181 | 1,367 | $456,687 | 1,269 | $404,775 |
| Cement, portland ______________do____ | 7,567 | 420,949 | 8,715 | 520,026 | 9,462 | 601,506 |
| Clays[2] ___________________do____ | 1,816 | 18,255 | 2,100 | 23,868 | 2,203 | 26,600 |
| Gem stones______________________ | NA | 300 | NA | 500 | NA | 550 |
| Gold (recoverable content of ores, etc.) troy ounces__ | 38,443 | 16,300 | 85,858 | 30,965 | 165,101 | 52,446 |
| Gypsum________ thousand short tons__ | 1,213 | 10,668 | 1,382 | 12,443 | 1,332 | 12,201 |
| Lime ___________________do____ | 358 | 22,994 | 406 | 26,827 | 367 | 24,733 |
| Peat ___________________do____ | 13 | 612 | W | W | W | W |
| Pumice _________________do____ | 65 | 1,582 | 80 | 1,600 | 78 | 1,491 |
| Sand and gravel: | | | | | | |
| Construction______________do____ | [e]91,000 | [e]308,700 | 102,420 | 360,427 | [e]112,800 | [e]430,000 |
| Industrial ______________do____ | 2,150 | 34,066 | 2,281 | 39,176 | 2,255 | 37,484 |
| Silver (recoverable content of ores, etc.) thousand troy ounces__ | 27 | 308 | W | W | 115 | 709 |
| Stone: | | | | | | |
| Crushed______ thousand short tons__ | 35,582 | 146,289 | [e]38,600 | [e]158,000 | 41,199 | 174,395 |
| Dimension ______________do____ | 20 | 2,839 | [e]22 | [e]2,990 | 23 | 2,449 |
| Talc and pyrophyllite __________do____ | 71 | 1,289 | 74 | 1,642 | 100 | 2,493 |
| Combined value of asbestos, calcium chloride, cement (masonry), clays (fire clay), copper, diatomite, feldspar, iron ore, lead (1984), magnesium compounds, molybdenum (1984-85), perlite, potassium salts, rare-earth metal concentrates, salt, sodium carbonate, sodium sulfate, tungsten ore and concentrate, wollastonite (1983-84), and values indicated by symbol W ________ | XX | 359,218 | XX | [r]360,085 | XX | 323,014 |
| Total___________________ | XX | 1,783,550 | XX | [r]1,995,236 | XX | 2,094,796 |
| **COLORADO** | | | | | | |
| Clays __________ thousand short tons__ | 459 | $2,650 | 308 | $2,111 | 303 | $1,743 |
| Gem stones______________________ | NA | 80 | NA | 80 | NA | 80 |
| Gold (recoverable content of ores, etc.) troy ounces__ | 68,063 | 26,739 | 60,010 | 21,643 | 43,301 | 13,755 |
| Gypsum________ thousand short tons__ | W | W | 291 | W | 233 | 1,800 |
| Sand and gravel: | | | | | | |
| Construction______________do____ | [e]21,200 | [e]81,600 | 28,024 | 87,324 | [e]27,500 | [e]88,000 |
| Industrial ______________do____ | 212 | 3,233 | 149 | 2,213 | W | W |
| Silver (recoverable content of ores, etc.) thousand troy ounces__ | 2,146 | 24,546 | 2,200 | 17,909 | 549 | 3,370 |
| Stone: | | | | | | |
| Crushed______ thousand short tons__ | 6,790 | 22,749 | [e]7,200 | [e]26,200 | 7,037 | 25,930 |
| Dimension ______________do____ | 1 | 86 | [e]1 | [e]87 | 2 | 204 |
| Combined value of cement, copper, iron ore, lead, lime, molybdenum, peat, perlite, pyrites (1984-85), salt (1984), tin (1984-85), tungsten ore and concentrate, vanadium (1983-84), zinc, and values indicated by symbol W ___________________ | XX | 175,969 | XX | [r]278,609 | XX | 273,296 |
| Total___________________ | XX | 337,652 | XX | [r]436,176 | XX | 408,178 |
| **CONNECTICUT** | | | | | | |
| Clays __________ thousand short tons__ | 86 | $515 | 99 | $565 | 106 | $632 |
| Lime ___________________do____ | 5 | 400 | W | W | -- | -- |
| Sand and gravel (construction)____do____ | [e]5,000 | [e]17,900 | 6,718 | 22,817 | [e]6,000 | [e]21,000 |
| Stone: | | | | | | |
| Crushed_________________do____ | 7,692 | 45,890 | [e]8,300 | [e]49,400 | 7,277 | 43,937 |
| Dimension ______________do____ | 18 | 1,028 | [e]18 | [e]1,080 | 20 | 1,285 |
| Combined value of feldspar, gem stones, mica (scrap), sand and gravel (industrial), and value indicated by symbol W_________ | XX | 5,480 | XX | 5,834 | XX | 5,532 |
| Total___________________ | XX | 71,218 | XX | 79,696 | XX | 72,386 |
| **DELAWARE** | | | | | | |
| Marl (greensand) __ thousand short tons__ | -- | -- | 1 | $18 | 2 | $29 |
| Sand and gravel (construction)____do____ | [e]1,400 | [e]$3,200 | 1,003 | 2,795 | [e]1,300 | [e]4,000 |
| Total[4] ___________________ | XX | 3,200 | XX | 2,818 | XX | 4,029 |

See footnotes at end of table.

## Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

| Mineral | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| **FLORIDA** |  |  |  |  |  |  |
| Cement: |  |  |  |  |  |  |
| Masonry ----- thousand short tons-- | 318 | $19,557 | 383 | $24,624 | 316 | $17,137 |
| Portland ---------------do---- | 3,329 | 164,048 | 3,564 | 172,548 | 3,282 | 148,908 |
| Clays ---------------------do---- | 684 | 31,566 | 772 | 34,048 | 672 | 33,074 |
| Gem stones------------------------ | NA | 6 | NA | 6 | NA | 6 |
| Lime --------- thousand short tons-- | W | 13,881 | 171 | 9,379 | W | W |
| Peat ----------------------do---- | 114 | 1,999 | 263 | 5,454 | 243 | 5,333 |
| Sand and gravel: |  |  |  |  |  |  |
| Construction--------------do---- | •14,900 | •31,500 | 21,032 | 48,494 | •22,500 | •49,500 |
| Industrial ---------------do---- | 329 | 3,447 | 1,533 | 9,815 | 2,123 | 12,642 |
| Stone (crushed) -------------do---- | 57,282 | 235,700 | •68,500 | •290,000 | 69,266 | 287,237 |
| Combined value of magnesium compounds, phosphate rock, rare-earth metal concentrates, staurolite, titanium concentrates (ilmenite and rutile), zircon concentrates, and value indicated by symbol W ------ | XX | 774,122 | XX | 915,996 | XX | 1,005,429 |
| Total-------------------- | XX | 1,275,826 | XX | 1,510,364 | XX | 1,559,266 |
| **GEORGIA** |  |  |  |  |  |  |
| Clays --------- thousand short tons-- | 7,859 | $560,005 | 8,679 | $600,029 | 8,671 | $575,097 |
| Gem stones------------------------ | NA | 20 | NA | 20 | NA | 20 |
| Sand and gravel: |  |  |  |  |  |  |
| Construction--- thousand short tons-- | •3,800 | •9,400 | 5,347 | 13,623 | •5,000 | •13,400 |
| Industrial ---------------do---- | 539 | 7,298 | 478 | 6,795 | 571 | 6,675 |
| Stone: |  |  |  |  |  |  |
| Crushed-----------------do---- | 41,100 | 186,193 | •45,900 | •220,000 | 52,062 | 256,588 |
| Dimension ---------------do---- | 183 | 21,019 | •202 | •20,007 | 185 | 19,466 |
| Talc ----------------------do---- | 14 | 101 | 15 | 104 | 16 | 111 |
| Combined value of barite, bauxite (1983-84), cement, feldspar, iron oxide pigments (crude), kyanite, mica (scrap), and peat--- | XX | 65,536 | XX | 79,914 | XX | 74,718 |
| Total-------------------- | XX | 849,572 | XX | 940,492 | XX | 946,075 |
| **HAWAII** |  |  |  |  |  |  |
| Cement: |  |  |  |  |  |  |
| Masonry ----- thousand short tons-- | 6 | $641 | 5 | $792 | 7 | $588 |
| Portland ---------------do---- | 216 | 20,673 | 186 | 18,282 | 16 | 16,050 |
| Sand and gravel (construction) thousand short tons-- | •440 | •1,000 | 436 | 2,031 | •500 | •2,100 |
| Stone: |  |  |  |  |  |  |
| Crushed-----------------do---- | 5,532 | 29,703 | •5,400 | •29,700 | 5,627 | 34,183 |
| Dimension ---------------do---- | (3) | 3 | -- | -- | -- | -- |
| Combined value of other industrial minerals | XX | 391 | XX | 442 | XX | 351 |
| Total-------------------- | XX | 52,411 | XX | 51,247 | XX | 53,272 |
| **IDAHO** |  |  |  |  |  |  |
| Antimony ore and concentrate, antimony content--------------short tons-- | 585 | W | 557 | W | W | W |
| Clays --------- thousand short tons-- | 6 | $91 | •1 | W | •2 | W |
| Copper (recoverable content of ores, etc.) metric tons-- | 3,556 | 6,000 | 3,701 | $5,455 | 3,551 | $5,242 |
| Gem stones------------------------ | NA | 100 | NA | 150 | NA | 175 |
| Gold (recoverable content of ores, etc.) troy ounces-- | W | W | W | W | 44,306 | 14,074 |
| Lead (recoverable content of ores, etc.) metric tons-- | 25,893 | 12,376 | W | W | 33,707 | 14,169 |
| Lime --------- thousand short tons-- | 85 | 7,686 | 87 | 5,616 | 93 | 5,803 |
| Phosphate rock -- thousand metric tons-- | W | W | 4,722 | 126,586 | 3,784 | 102,430 |
| Sand and gravel (construction) thousand short tons-- | •3,000 | •9,800 | 4,725 | 13,509 | •4,000 | •11,400 |
| Silver (recoverable content of ores, etc.) thousand troy ounces-- | 17,684 | 202,308 | 18,869 | 153,608 | 18,828 | 115,645 |
| Stone (crushed) --- thousand short tons-- | 1,935 | 7,480 | •1,800 | •7,100 | 2,019 | 6,977 |

See footnotes at end of table.

## Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

| Mineral | 1983 Quantity | 1983 Value (thousands) | 1984 Quantity | 1984 Value (thousands) | 1985 Quantity | 1985 Value (thousands) |
|---|---|---|---|---|---|---|
| **IDAHO—Continued** | | | | | | |
| Combined value of cement, clays (bentonite and fire clay, 1984-85; fuller's earth, 1985) garnet (abrasive), gypsum (1984), molybdenum (1984-85), perlite, pumice, sand and gravel (industrial), stone (dimension), tungsten ore and concentrate (1983), vanadium (1984-85), zinc, and values indicated by symbol W | XX | $169,318 | XX | [r]$100,326 | XX | $72,239 |
| Total | XX | 415,159 | XX | [r]412,350 | XX | 348,154 |
| **ILLINOIS** | | | | | | |
| Cement (portland) thousand short tons | 1,857 | $74,975 | 1,997 | $82,622 | 2,101 | $86,211 |
| Clays[2] do | 717 | 3,360 | 253 | 940 | 265 | 876 |
| Gem stones | NA | 15 | NA | 15 | NA | 15 |
| Peat thousand short tons | W | W | 49 | W | W | W |
| Sand and gravel: | | | | | | |
| Construction do | •21,100 | •58,400 | 25,969 | 72,477 | •26,600 | •77,000 |
| Industrial do | 4,060 | 42,871 | 4,100 | 52,197 | 4,056 | 56,915 |
| Stone: | | | | | | |
| Crushed do | 42,761 | 166,860 | •48,500 | •191,600 | 41,044 | 164,117 |
| Dimension do | 2 | 71 | -- | -- | 2 | 107 |
| Combined value of barite, cement (masonry), clays (fuller's earth), copper (1985), fluorspar, lead, lime, silver, tripoli, zinc, and values indicated by symbol W | XX | 60,355 | XX | 72,010 | XX | 74,679 |
| Total | XX | 406,907 | XX | 471,861 | XX | 459,920 |
| **INDIANA** | | | | | | |
| Clays thousand short tons | [2]558 | [2]$1,421 | [2]653 | [2]$2,085 | 740 | $2,776 |
| Gem stones | NA | 1 | NA | 1 | NA | 1 |
| Peat thousand short tons | 81 | 1,973 | 61 | 1,358 | 54 | W |
| Sand and gravel: | | | | | | |
| Construction do | •14,400 | •37,900 | 16,071 | 44,744 | •18,600 | •55,800 |
| Industrial do | W | W | 194 | 1,129 | 182 | 1,209 |
| Stone: | | | | | | |
| Crushed do | 24,051 | 82,782 | •26,700 | •99,400 | •23,384 | •81,119 |
| Dimension do | 144 | 11,015 | •159 | •14,269 | 188 | 20,186 |
| Combined value of abrasives (natural), cement, clays (fire clay, 1983-84), gypsum, lime, stone (crushed marl, 1985), and values indicated by symbol W | XX | 115,450 | XX | 130,250 | XX | 141,863 |
| Total | XX | 250,542 | XX | 293,236 | XX | 302,954 |
| **IOWA** | | | | | | |
| Cement: | | | | | | |
| Masonry thousand short tons | 37 | $3,425 | 42 | $3,260 | 39 | $3,372 |
| Portland do | 1,644 | 87,836 | 1,730 | 92,699 | 1,618 | 77,890 |
| Clays do | 576 | 3,258 | 623 | 2,695 | 503 | 2,450 |
| Gem stones | NA | 1 | NA | W | NA | 1 |
| Gypsum thousand short tons | 1,612 | 13,518 | 1,527 | 12,421 | 1,639 | 13,682 |
| Peat do | W | W | 11 | 400 | 11 | 415 |
| Sand and gravel (construction) do | •11,800 | •32,800 | 13,882 | 37,027 | •12,000 | •30,500 |
| Stone (crushed) do | 24,844 | 101,097 | •23,800 | •100,000 | 23,657 | 94,496 |
| Combined value of lime, stone (dimension, 1983, 1985), and values indicated by symbol W | XX | 5,425 | XX | 4,943 | XX | 5,211 |
| Total | XX | 247,360 | XX | 253,445 | XX | 228,017 |
| **KANSAS** | | | | | | |
| Clays thousand short tons | 718 | $3,921 | 918 | $5,537 | 878 | $5,326 |
| Gem stones | NA | 1 | NA | 1 | NA | 1 |
| Helium: | | | | | | |
| Crude million cubic feet | 188 | 3,572 | 402 | 8,844 | W | W |
| Grade-A do | 775 | 27,125 | 1,015 | 38,063 | W | W |
| Salt[7] thousand short tons | 1,719 | 67,195 | 1,712 | 71,558 | 1,790 | 71,970 |

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

| Mineral | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| KANSAS—Continued | | | | | | |
| Sand and gravel: | | | | | | |
| Construction thousand short tons | [e]12,400 | [e]$26,600 | 11,796 | $26,358 | [e]13,200 | [e]$31,800 |
| Industrial do | 199 | 2,184 | W | W | 184 | 1,124 |
| Stone (crushed) do | 12,687 | 45,121 | [e]13,600 | [e]48,500 | 15,653 | 57,155 |
| Combined value of cement, gypsum, lime (1983-84), pumice, salt (brine), stone (dimension), and values indicated by symbol W | XX | 91,866 | XX | 113,149 | XX | 154,794 |
| Total | XX | 267,585 | XX | 312,010 | XX | 322,170 |
| KENTUCKY | | | | | | |
| Clays thousand short tons | [2]669 | [2]$2,142 | [r] [2]662 | [r] [2]$2,533 | 775 | $6,487 |
| Gem stones | NA | 1 | NA | 1 | NA | 1 |
| Sand and gravel: | | | | | | |
| Construction thousand short tons | [e]5,500 | [e]13,000 | 7,839 | 18,252 | [e]7,600 | [e]19,000 |
| Industrial do | 10 | 124 | W | W | W | W |
| Stone (crushed) do | 33,399 | 117,842 | [e]37,300 | [e]133,000 | [3]38,022 | [3]134,978 |
| Combined value of cement, clays (ball clay, 1983-84, fire clay, 1983), lime, stone (crushed sandstone, 1985), zinc, and values indicated by symbol W | XX | 91,408 | XX | [r]103,422 | XX | 107,092 |
| Total | XX | 224,517 | XX | [r]257,208 | XX | 267,558 |
| LOUISIANA | | | | | | |
| Clays thousand short tons | [2]505 | $10,798 | 547 | [2]$10,858 | 334 | $7,017 |
| Gem stones | NA | 1 | NA | 1 | NA | 1 |
| Salt thousand short tons | 11,544 | 100,936 | 13,101 | 112,142 | 12,325 | 138,955 |
| Sand and gravel: | | | | | | |
| Construction do | [e]14,200 | [e]46,600 | 17,040 | 54,664 | [e]15,000 | [e]48,000 |
| Industrial do | 291 | 4,252 | 266 | 3,757 | 267 | 3,838 |
| Stone (crushed) do | 5,758 | 25,702 | [e]4,100 | [e]19,500 | [e]4,820 | [e]25,956 |
| Sulfur (Frasch) thousand metric tons | 1,643 | W | 2,007 | W | 1,698 | W |
| Combined value of cement, clays (bentonite, 1984), gypsum, lime, stone (crushed miscellaneous, 1985), and values indicated by symbol W | XX | 258,477 | XX | 310,548 | XX | 298,501 |
| Total | XX | 446,761 | XX | 511,470 | XX | 522,268 |
| MAINE | | | | | | |
| Clays thousand short tons | 48 | $93 | 48 | $97 | 50 | $100 |
| Gem stones | NA | W | NA | 400 | NA | 400 |
| Sand and gravel (construction) thousand short tons | [e]4,800 | [e]12,100 | 7,885 | 19,228 | [e]7,200 | [e]18,000 |
| Stone (crushed) do | 848 | 2,851 | [e]1,300 | [e]4,400 | 1,459 | 5,114 |
| Combined value of cement, garnet (abrasive), peat (1983-84), and stone (dimension) | XX | 11,319 | XX | [r]13,814 | XX | 17,494 |
| Total | XX | 26,363 | XX | 37,939 | XX | 41,108 |
| MARYLAND | | | | | | |
| Clays[2] thousand short tons | 484 | $1,747 | 347 | $1,484 | 336 | $1,647 |
| Gem stones | NA | 2 | NA | 2 | NA | 2 |
| Lime thousand short tons | 7 | 383 | 7 | 419 | 10 | 608 |
| Peat do | 4 | W | 5 | W | W | W |
| Sand and gravel (construction) do | [e]10,600 | [e]37,800 | 14,234 | 46,671 | [e]17,000 | [e]58,000 |
| Stone: | | | | | | |
| Crushed do | 19,284 | 80,429 | [e]22,100 | [e]94,000 | 24,406 | 98,584 |
| Dimension do | 12 | 682 | [e]17 | [e]864 | 18 | 1,218 |
| Combined value of cement, clays (ball clay), sand and gravel (industrial, 1984-85), and values indicated by symbol W | XX | 78,366 | XX | 98,261 | XX | 98,215 |
| Total | XX | 199,409 | XX | 241,701 | XX | 258,274 |

See footnotes at end of table.

## Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

| Mineral | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| **MASSACHUSETTS** | | | | | | |
| Clays thousand short tons | 237 | $1,298 | 240 | $1,212 | 265 | $1,388 |
| Lime do. | 156 | 10,671 | 171 | 12,426 | 159 | 10,935 |
| Sand and gravel (construction) do. | [e]10,400 | [e]36,200 | 14,168 | 42,189 | [e]14,900 | [e]47,500 |
| Stone: | | | | | | |
| Crushed do. | 7,740 | 36,002 | [e]8,400 | [e]39,000 | 9,354 | 42,881 |
| Dimension do. | 51 | 10,488 | [e]57 | [e]11,657 | 73 | 13,724 |
| Combined value of gem stones, peat, and sand and gravel (industrial) | XX | 1,016 | XX | 898 | XX | 777 |
| Total | XX | 95,675 | XX | 107,332 | XX | 117,205 |
| **MICHIGAN** | | | | | | |
| Clays thousand short tons | 1,199 | $5,693 | 1,321 | $5,052 | 1,477 | $5,514 |
| Gem stones | NA | 15 | NA | 15 | NA | 15 |
| Gypsum thousand short tons | 1,097 | 8,104 | 1,534 | 10,304 | 1,772 | 11,888 |
| Iron ore (usable) thousand long tons, gross weight | 10,713 | W | 13,263 | W | 12,629 | W |
| Lime thousand short tons | 503 | 23,142 | 622 | 30,092 | 535 | 24,790 |
| Peat do. | 215 | 4,286 | 227 | 4,341 | 282 | 5,414 |
| Salt do. | 1,355 | 93,306 | 1,491 | 93,860 | 991 | 75,030 |
| Sand and gravel: | | | | | | |
| Construction do. | [e]23,000 | [e]52,800 | 36,071 | 76,540 | [e]38,000 | [e]93,000 |
| Industrial do. | 3,545 | 27,577 | 3,400 | 33,060 | 3,345 | 25,469 |
| Stone: | | | | | | |
| Crushed do. | 24,763 | 82,152 | [e]28,100 | [e]92,000 | 30,685 | 95,953 |
| Dimension do. | 4 | 112 | [e]4 | [e]129 | 4 | 113 |
| Combined value of bromine, calcium chloride, cement, copper (1985), gold (1985), iodine, iron oxide pigments (crude), magnesium compounds, silver (1985), and values indicated by symbol W | XX | 882,239 | XX | 1,063,214 | XX | 1,010,672 |
| Total | XX | 1,178,926 | XX | 1,408,607 | XX | 1,347,853 |
| **MINNESOTA** | | | | | | |
| Gem stones | NA | $5 | NA | $5 | NA | $5 |
| Iron ore (usable) thousand long tons, gross weight | 30,699 | 1,342,455 | 35,602 | 1,561,516 | 34,977 | 1,430,358 |
| Manganiferous ore short tons | 11,314 | W | 68,019 | W | -- | -- |
| Peat thousand short tons | W | W | 24 | W | 34 | 1,720 |
| Sand and gravel: | | | | | | |
| Construction do. | [e]24,600 | [e]53,000 | 22,612 | 49,087 | [e]25,000 | [e]55,500 |
| Industrial do. | 685 | 12,932 | W | W | 884 | 16,910 |
| Stone: | | | | | | |
| Crushed do. | 8,580 | 25,320 | [e]8,900 | [e]25,800 | 7,756 | 22,601 |
| Dimension do. | 28 | 11,365 | [e]39 | [e]13,369 | 37 | 13,598 |
| Combined values of clays, lime, and values indicated by symbol W | XX | 9,953 | XX | 26,470 | XX | 7,271 |
| Total | XX | 1,455,030 | XX | 1,676,247 | XX | 1,547,958 |
| **MISSISSIPPI** | | | | | | |
| Clays thousand short tons | 1,446 | $23,846 | [r][2]1,274 | [r][2]$10,366 | 1,558 | $34,864 |
| Sand and gravel (construction) do. | [e]11,000 | [e]34,600 | 12,205 | 34,955 | [e]13,400 | [e]42,000 |
| Stone (crushed) do. | 1,651 | 4,377 | [e]2,000 | [e]5,800 | 1,582 | 4,282 |
| Combined value of cement, clays (ball clay and fuller's earth, 1984), and sand and gravel (industrial) | XX | 26,882 | XX | [r]42,016 | XX | 21,647 |
| Total | XX | 89,705 | XX | [r]93,187 | XX | 102,793 |
| **MISSOURI** | | | | | | |
| Barite thousand short tons | W | W | W | W | 47 | $2,791 |
| Cement: | | | | | | |
| Masonry do. | 146 | $7,339 | 148 | $7,033 | 139 | 6,630 |
| Portland do. | 3,499 | 157,249 | 3,981 | 178,225 | 3,669 | 159,757 |
| Clays[2] do. | 1,418 | 11,848 | 1,575 | 14,666 | 1,545 | 10,271 |
| Copper (recoverable content of ores, etc.) metric tons | 7,725 | 13,038 | 5,818 | 8,575 | 13,410 | 19,797 |
| Gem stones | NA | 10 | NA | 10 | NA | 10 |
| Iron ore (usable) thousand long tons, gross weight | 877 | 27,054 | 1,370 | W | 1,110 | W |
| Lead (recoverable content of ores, etc.) metric tons | 409,280 | 195,620 | 278,329 | 156,766 | 371,008 | 155,955 |

See footnotes at end of table.

## Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

| Mineral | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| **MISSOURI—Continued** | | | | | | |
| Sand and gravel: | | | | | | |
| Construction ___ thousand short tons __ | [e]7,700 | [e]$17,700 | 7,967 | $19,364 | [e]7,500 | [e]$20,000 |
| Industrial ______________ do ____ | 600 | 7,541 | 614 | 8,129 | 535 | 7,380 |
| Silver (recoverable content of ores, etc.) thousand troy ounces __ | 2,021 | 23,124 | 1,401 | 11,406 | 1,685 | 10,044 |
| Stone (crushed) ___ thousand short tons __ | 39,454 | 120,700 | [e]41,600 | [e]137,000 | 50,646 | 162,097 |
| Zinc (recoverable content of ores, etc.) metric tons __ | 57,044 | 52,052 | 45,458 | 48,707 | 49,340 | 43,908 |
| Combined value of clays (fuller's earth), iron oxide pigments (crude), lime, stone (dimension), and values indicated by symbol W __ | XX | 92,598 | XX | 142,016 | XX | 136,370 |
| Total ____________________ | XX | 725,868 | XX | 731,897 | XX | 784,960 |
| **MONTANA** | | | | | | |
| Antimony ______________ short tons __ | 253 | W | -- | -- | -- | -- |
| Barite _________ thousand short tons __ | 10 | $750 | W | W | W | W |
| Clays ____________________ do ____ | 194 | 6,205 | [r]229 | [r]$5,642 | 279 | $8,296 |
| Copper (recoverable content of ores, etc.) metric tons __ | 33,337 | 56,245 | W | W | 15,092 | 22,281 |
| Gem stones ____________________ | NA | 300 | NA | 450 | NA | 400 |
| Gold (recoverable content of ores, etc.) troy ounces __ | 161,436 | 68,449 | 181,190 | 65,348 | 160,262 | 50,909 |
| Lead (recoverable content of ores, etc.) metric tons __ | 1,163 | 556 | W | W | 846 | 356 |
| Lime _________ thousand short tons __ | 86 | W | 89 | 5,097 | W | W |
| Sand and gravel (construction) ____ do ____ | [e]5,000 | [e]10,200 | 7,776 | 21,269 | [e]9,000 | [e]26,000 |
| Silver (recoverable content of ores, etc.) thousand troy ounces __ | 5,708 | 65,299 | 5,658 | 46,018 | 4,010 | 24,630 |
| Stone (crushed) ___ thousand short tons __ | 872 | 2,320 | [e]950 | [e]2,400 | [10e]1,730 | [10e]5,044 |
| Combined value of cement, graphite (1983-84), gypsum, iron ore, molybdenum (1983), peat, phosphate rock, sand and gravel (industrial), stone (crushed traprock, 1985), stone (dimension), talc, vermiculite, and values indicated by symbol W __________ | XX | 81,644 | XX | [r]93,811 | XX | 62,356 |
| Total ____________________ | XX | 291,968 | XX | [r]240,085 | XX | 200,272 |
| **NEBRASKA** | | | | | | |
| Clays _________ thousand short tons __ | 164 | $501 | 180 | $556 | 244 | $718 |
| Gem stones ____________________ | NA | W | NA | W | NA | 10 |
| Sand and gravel: | | | | | | |
| Construction ___ thousand short tons __ | [e]10,100 | [e]25,000 | 11,839 | 27,791 | [e]11,600 | [e]28,800 |
| Industrial ______________ do ____ | 4 | W | W | W | W | W |
| Stone (crushed) ______________ do ____ | 4,442 | 22,612 | [e]4,500 | [e]23,400 | 4,175 | 19,134 |
| Combined value of cement, lime, and values indicated by symbol W __________ | XX | 39,296 | XX | 48,621 | XX | 51,308 |
| Total ____________________ | XX | 87,409 | XX | 100,368 | XX | 99,970 |
| **NEVADA** | | | | | | |
| Barite _________ thousand short tons __ | 663 | $21,736 | 615 | $14,924 | 590 | $10,904 |
| Clays ____________________ do ____ | 58 | 2,348 | [8]20 | [8]1,191 | [8]80 | [8]3,776 |
| Gem stones ____________________ | NA | 1,200 | NA | 1,300 | NA | 1,300 |
| Gold (recoverable content of ores, etc.) troy ounces __ | [r]960,657 | [r]407,319 | [r]1,020,546 | [r]368,068 | 1,276,114 | 405,369 |
| Gypsum _______ thousand short tons __ | 998 | 7,896 | 1,192 | 8,860 | 1,207 | 8,942 |
| Lead (recoverable content of ores, etc.) metric tons __ | 14 | 7 | W | W | (8) | (8) |
| Mercury __________ 76-pound flasks __ | 25,070 | W | 19,048 | W | 16,530 | W |
| Sand and gravel: | | | | | | |
| Construction ___ thousand short tons __ | [e]7,500 | [e]16,200 | 8,202 | 20,505 | [e]9,500 | [e]24,800 |
| Industrial ______________ do ____ | W | W | 489 | W | 479 | W |
| Silver (recoverable content of ores, etc.) thousand troy ounces __ | [r]5,179 | [r]59,252 | 6,477 | 52,727 | 4,947 | 30,383 |
| Stone (crushed) ___ thousand short tons __ | 1,269 | 5,358 | [e]1,100 | [e]4,700 | 1,334 | 6,218 |
| Combined value of cement (portland), clays (fuller's earth and kaolin, 1984-85), copper, diatomite, fluorspar, iron ore, lime, lithium compounds, magnesite, molybdenum, perlite, salt, tungsten ore and concentrate (1984), and values indicated by symbol W _ | XX | 111,178 | XX | 151,787 | XX | 139,191 |
| Total ____________________ | XX | [r]632,494 | XX | [r]624,062 | XX | 630,883 |

See footnotes at end of table.

## Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

| Mineral | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| **NEW HAMPSHIRE** | | | | | | |
| Sand and gravel (construction) thousand short tons | [e]4,000 | [e]$12,100 | 5,637 | $16,054 | [e]6,300 | [e]$19,800 |
| Stone: | | | | | | |
| Crushed do | 946 | 2,853 | [e]850 | [e]2,700 | 1,612 | 6,434 |
| Dimension do | 58 | 4,032 | [e]59 | [e]4,198 | 79 | 6,532 |
| Combined value of other industrial minerals | XX | 101 | XX | 160 | XX | 134 |
| Total | XX | 19,086 | XX | 23,112 | XX | 32,900 |
| **NEW JERSEY** | | | | | | |
| Clays thousand short tons | 62 | $596 | [r]62 | $611 | 130 | $2,050 |
| Gem stones | NA | 1 | NA | 1 | NA | 1 |
| Peat thousand short tons | W | W | 5 | 128 | W | 311 |
| Sand and gravel: | | | | | | |
| Construction do | [e]10,800 | [e]34,300 | 9,545 | $31,878 | [e]10,600 | [e]36,700 |
| Industrial do | 2,386 | 31,819 | 2,712 | 32,287 | 2,820 | 31,119 |
| Stone (crushed) | 12,301 | 70,421 | [e]13,500 | [e]75,000 | 15,692 | 94,339 |
| Zinc (recoverable content of ores, etc.) metric tons | 16,475 | 15,033 | W | W | W | W |
| Combined value of magnesium compounds (1983), marl (greensand), stone (dimension, 1983-84), and values indicated by symbol W | XX | 2,445 | XX | 16,331 | XX | 13,056 |
| Total | XX | 154,615 | XX | 156,236 | XX | 177,576 |
| **NEW MEXICO** | | | | | | |
| Clays thousand short tons | 50 | $115 | 67 | $143 | 60 | $161 |
| Gem stones | NA | 200 | NA | 200 | NA | 200 |
| Gold (recoverable content of ores, etc.) troy ounces | W | W | W | W | 45,045 | 14,309 |
| Gypsum thousand short tons | 169 | 1,016 | 318 | 1,622 | 350 | 1,570 |
| Lead (recoverable content of ores, etc.) metric tons | 258 | 123 | -- | -- | W | W |
| Lime thousand short tons | 17 | W | -- | -- | -- | -- |
| Perlite do | 394 | 13,297 | 416 | 14,115 | 419 | 14,521 |
| Potassium salts thousand metric tons | 1,278 | 174,700 | 1,418 | 204,100 | 1,120 | 156,000 |
| Pumice thousand short tons | 110 | 1,070 | 132 | 1,269 | 152 | 1,114 |
| Sand and gravel (construction) do | [e]7,000 | [e]20,000 | 8,363 | 22,389 | [e]8,400 | [e]22,800 |
| Stone: | | | | | | |
| Crushed do | 4,730 | 15,118 | [e]4,700 | [e]17,000 | 3,641 | 15,232 |
| Dimension do | 18 | 141 | [e]19 | [e]149 | 20 | 277 |
| Combined value of cement, copper, helium (Grade-A), mica (scrap), molybdenum, salt, silver, tungsten ore and concentrate (1984), and values indicated by symbol W | XX | 291,411 | XX | [r]374,855 | XX | 430,705 |
| Total | XX | 517,191 | XX | [r]635,842 | XX | 656,889 |
| **NEW YORK** | | | | | | |
| Clays thousand short tons | [2]371 | [2]$869 | [2]543 | [2]$2,435 | 700 | $3,129 |
| Gem stones | NA | 30 | NA | 30 | NA | 30 |
| Lead (recoverable content of ores, etc.) metric tons | 1,299 | 621 | W | W | W | W |
| Peat thousand short tons | 18 | W | W | W | W | W |
| Salt do | 4,859 | 100,119 | 5,644 | 123,755 | 6,928 | 142,318 |
| Sand and gravel: | | | | | | |
| Construction do | [e]18,700 | [e]54,200 | 25,968 | 80,866 | [e]28,000 | [e]88,500 |
| Industrial do | W | W | 25 | 260 | W | W |
| Silver (recoverable content of ores, etc.) thousand troy ounces | 33 | 379 | W | W | W | W |
| Stone: | | | | | | |
| Crushed thousand short tons | 31,991 | 134,752 | [e]33,100 | [e]135,000 | 35,139 | 165,136 |
| Dimension do | 24 | 4,310 | [e]15 | [e]4,271 | 16 | 3,666 |
| Zinc (recoverable content of ores, etc.) metric tons | 56,748 | 51,783 | W | W | W | W |
| Combined value of cement, clays (ball clay, 1983-84), emery, garnet (abrasive), gypsum, lime, talc, titanium concentrate (ilmenite, 1983-84), wollastonite, and values indicated by symbol W | XX | 156,351 | XX | 265,873 | XX | 254,529 |
| Total | XX | 503,414 | XX | 612,490 | XX | 657,308 |

See footnotes at end of table.

Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

| Mineral | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| **NORTH CAROLINA** | | | | | | |
| Clays ---------- thousand short tons-- | [3]2,068 | [3]$6,681 | 2,327 | $8,987 | 2,688 | $10,477 |
| Feldspar ----------------short tons-- | 508,641 | 18,610 | 510,275 | 13,994 | 490,993 | 13,351 |
| Gem stones---------------------- | NA | 50 | NA | 50 | NA | 50 |
| Mica (scrap) ----- thousand short tons-- | 69 | 4,266 | 79 | 3,762 | 80 | 3,726 |
| Sand and gravel: | | | | | | |
| Construction---------------do---- | $^e$5,600 | $^e$16,900 | 6,312 | 18,159 | $^e$6,100 | $^e$19,500 |
| Industrial ----------------do---- | 1,066 | 11,689 | 1,158 | 12,864 | 1,294 | 13,086 |
| Stone: | | | | | | |
| Crushed------------------do---- | 33,694 | 145,001 | $^e$38,100 | $^e$168,000 | 41,771 | 194,818 |
| Dimension ----------------do---- | 87 | 8,267 | W | W | 85 | 6,132 |
| Talc and pyrophyllite ----------do---- | 89 | 1,452 | 87 | 1,587 | 85 | 1,604 |
| Combined value of cement (1983), clays (kaolin, 1983), lithium compounds, olivine, peat, phosphate rock, and value indicated by symbol W ------------------ | XX | 190,641 | XX | 224,077 | XX | 170,012 |
| Total--------------------- | XX | 398,557 | XX | 451,480 | XX | 432,756 |
| **NORTH DAKOTA** | | | | | | |
| Gem stones---------------------- | NA | $2 | NA | $2 | NA | $2 |
| Lime ---------- thousand short tons-- | 57 | 6,798 | 60 | 5,912 | 56 | 5,562 |
| Sand and gravel (construction)----do---- | $^e$3,800 | $^e$15,000 | 6,426 | 11,351 | $^e$6,900 | $^e$13,800 |
| Combined value of clays, peat, salt, and stone (crushed, 1985) ------------------ | XX | 3,570 | XX | 4,529 | XX | 4,820 |
| Total--------------------- | XX | 25,370 | XX | 21,794 | XX | 24,184 |
| **OHIO** | | | | | | |
| Cement: | | | | | | |
| Masonry ----- thousand short tons-- | 97 | $7,454 | 101 | $8,092 | 110 | $10,412 |
| Portland ------------------do---- | 1,575 | 71,599 | 1,525 | 69,810 | 1,769 | 84,929 |
| Clays ---------------------do---- | 1,716 | 8,061 | 1,960 | 10,478 | 2,114 | 10,581 |
| Gem stones---------------------- | NA | W | NA | W | NA | 10 |
| Lime ---------- thousand short tons-- | 1,906 | 84,928 | 1,859 | 87,951 | 1,730 | 84,142 |
| Peat-----------------------do---- | W | W | 18 | 345 | 16 | 418 |
| Salt ----------------------do---- | 2,565 | 85,988 | W | W | 4,788 | 148,949 |
| Sand and gravel: | | | | | | |
| Construction---------------do---- | $^e$27,200 | $^e$84,600 | 31,748 | 104,709 | $^e$33,000 | $^e$109,000 |
| Industrial ----------------do---- | 1,226 | 17,848 | 1,506 | 20,829 | 1,312 | 21,945 |
| Stone: | | | | | | |
| Crushed------------------do---- | 32,937 | 114,059 | $^e$38,500 | $^e$139,000 | 38,310 | 186,544 |
| Dimension ----------------do---- | 49 | 2,923 | $^e$37 | $^e$3,454 | 53 | 3,661 |
| Combined value of abrasives, gypsum, and values indicated by symbol W --------- | XX | 1,684 | XX | 108,240 | XX | 1,541 |
| Total--------------------- | XX | 479,144 | XX | 552,903 | XX | 607,127 |
| **OKLAHOMA** | | | | | | |
| Cement: | | | | | | |
| Masonry ----- thousand short tons-- | 45 | $3,074 | 49 | $3,506 | 48 | $2,854 |
| Portland ------------------do---- | 1,719 | 83,685 | 1,732 | 84,701 | 1,589 | 72,583 |
| Clays ---------------------do---- | 862 | 2,288 | 979 | 2,498 | 997 | 2,338 |
| Gem stones---------------------- | NA | 2 | NA | 2 | NA | 2 |
| Gypsum-------- thousand short tons-- | 1,351 | 11,571 | 1,549 | 13,485 | 1,595 | 12,548 |
| Pumice --------------------do---- | 1 | W | W | W | W | W |
| Sand and gravel: | | | | | | |
| Construction---------------do---- | $^e$7,500 | $^e$17,800 | 10,984 | 26,582 | $^e$12,600 | $^e$32,800 |
| Industrial ----------------do---- | 1,184 | 13,221 | W | W | W | W |
| Stone: | | | | | | |
| Crushed------------------do---- | 23,865 | 76,941 | $^e$25,500 | $^e$86,000 | 31,173 | 98,811 |
| Dimension ----------------do---- | 10 | 737 | $^e$12 | $^e$771 | 11 | 836 |
| Combined value of feldspar, iodine, lime, salt, tripoli, and values indicated by symbol W - | XX | 17,367 | XX | 28,187 | XX | 29,335 |
| Total--------------------- | XX | 226,186 | XX | 245,732 | XX | 251,607 |

See footnotes at end of table.

## Table 5.—Nonfuel mineral production[1] in the United States, by State—Continued

| Mineral | 1983 Quantity | 1983 Value (thousands) | 1984 Quantity | 1984 Value (thousands) | 1985 Quantity | 1985 Value (thousands) |
|---|---|---|---|---|---|---|
| **OREGON** | | | | | | |
| Clays ---------- thousand short tons-- | 188 | $275 | 189 | $288 | 188 | $285 |
| Gem stones---------------------- | NA | 600 | NA | 400 | NA | 350 |
| Gold (recoverable content of ores, etc.) troy ounces-- | 322 | 187 | W | W | W | W |
| Nickel (content of ores and concentrates) short tons-- | -- | -- | 14,540 | W | 6,127 | W |
| Sand and gravel (construction) thousand short tons-- | [e]11,000 | [e]37,000 | 12,776 | 37,117 | [e]12,500 | [e]36,800 |
| Silver (recoverable content of ores, etc.) thousand troy ounces-- | 1 | 10 | W | W | -- | -- |
| Stone (crushed) --- thousand short tons-- | 13,089 | 39,873 | [e]12,500 | [e]37,500 | 15,336 | 54,244 |
| Talc and soapstone ------------do---- | ([3]) | 123 | ([3]) | 66 | ([3]) | 30 |
| Combined value of cement, copper (1983), diatomite, lead (1983), lime, pumice, sand and gravel (industrial, 1983), stone (dimension, 1983 and 1985), and values indicated by symbol W ------------------ | XX | 32,922 | XX | 45,031 | XX | 38,587 |
| Total--------------------- | XX | 110,940 | XX | 120,402 | XX | 130,296 |
| **PENNSYLVANIA** | | | | | | |
| Cement: | | | | | | |
| Masonry ----- thousand short tons-- | 262 | $17,095 | 298 | $20,849 | 303 | $20,970 |
| Portland -----------------do---- | 5,154 | 218,539 | 5,735 | 281,590 | 5,535 | 288,036 |
| Clays[2]--------------------do---- | 916 | 4,311 | 963 | 4,050 | 1,142 | 5,293 |
| Gem stones---------------------- | NA | 5 | NA | 5 | NA | 5 |
| Lime ---------- thousand short tons-- | 1,507 | 81,682 | 1,620 | 90,182 | 1,492 | 85,269 |
| Peat--------------------do---- | 22 | 628 | 24 | 693 | 21 | 602 |
| Sand and gravel: | | | | | | |
| Construction--------------do---- | [e]11,800 | [e]52,000 | 14,472 | 64,285 | [e]17,000 | [e]74,000 |
| Industrial --------------do---- | W | W | W | W | 693 | 9,846 |
| Stone: | | | | | | |
| Crushed------------------do---- | 51,523 | 226,948 | [e]56,200 | [e]228,000 | 64,765 | 310,859 |
| Dimension ---------------do---- | 53 | 5,799 | [e]44 | [e]6,001 | 51 | 8,214 |
| Zinc (recoverable content of ores, etc.) metric tons-- | 16,792 | 15,322 | -- | -- | -- | -- |
| Combined value of clays (kaolin), mica (scrap), and values indicated by symbol W - | XX | 12,812 | XX | 12,701 | XX | 1,380 |
| Total--------------------- | XX | 635,141 | XX | 708,356 | XX | 804,474 |
| **RHODE ISLAND** | | | | | | |
| Sand and gravel (construction) thousand short tons-- | [e]1,000 | [e]$2,400 | 1,483 | $5,282 | [e]1,200 | [e]$4,600 |
| Stone (crushed) ---------------do---- | 971 | 5,507 | [e]1,000 | [e]5,800 | [10][e]1,135 | [10][e]7,016 |
| Combined value of gem stones, sand and gravel (industrial, 1984-85), and stone (crushed traprock, 1985)------------ | XX | 23 | XX | 486 | XX | 576 |
| Total--------------------- | XX | 7,930 | XX | 11,568 | XX | 12,192 |
| **SOUTH CAROLINA** | | | | | | |
| Cement, portland -- thousand short tons-- | W | W | 2,319 | $103,891 | 2,207 | $104,705 |
| Clays[2]--------------------do---- | 1,813 | $34,830 | 1,834 | 36,809 | 1,896 | 37,695 |
| Gem stones---------------------- | NA | 10 | NA | 10 | NA | 10 |
| Manganiferous ore - thousand short tons-- | 22 | W | 20 | W | 20 | W |
| Peat --------------------do---- | W | W | 5 | W | W | 173 |
| Sand and gravel: | | | | | | |
| Construction--------------do---- | [e]5,200 | [e]15,000 | 5,845 | 17,097 | [e]4,900 | [e]14,000 |
| Industrial ---------------do---- | 842 | 13,169 | 882 | 14,889 | 794 | 14,092 |
| Stone: | | | | | | |
| Crushed------------------do---- | 15,786 | 61,054 | [e]17,900 | [e]72,500 | 17,079 | 72,520 |
| Dimension ---------------do---- | 17 | 1,165 | [e]16 | [e]1,092 | 8 | 541 |
| Combined value of cement (masonry), clays (fuller's earth), gold (1985), mica (scrap), silver (1985), vermiculite, and values indicated by symbol W ------------ | XX | 105,366 | XX | 29,562 | XX | 32,193 |
| Total--------------------- | XX | 230,594 | XX | 275,850 | XX | 275,929 |

See footnotes at end of table.

## Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

| Mineral | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| SOUTH DAKOTA |  |  |  |  |  |  |
| Cement: |  |  |  |  |  |  |
| Masonry thousand short tons | 4 | $359 | 5 | $283 | 4 | W |
| Portland do. | 603 | 37,435 | 619 | 30,773 | 655 | W |
| Clays[2] do. | 123 | 353 | 119 | 343 | 117 | $309 |
| Feldspar short tons | 7,109 | 107 | 7,219 | 124 | 13,721 | W |
| Gem stones | NA | 70 | NA | 70 | NA | 70 |
| Gold (recoverable content of ores, etc.) troy ounces | 309,784 | 131,348 | 310,527 | 111,994 | 356,103 | 113,119 |
| Gypsum thousand short tons | W | W | W | W | 34 | 269 |
| Sand and gravel (construction) do. | [e]5,100 | [e]11,500 | 5,786 | 12,168 | [e]6,400 | [e]16,000 |
| Silver (recoverable content of ores, etc.) thousand troy ounces | 62 | 713 | 50 | 407 | 63 | 388 |
| Stone: |  |  |  |  |  |  |
| Crushed thousand short tons | 3,906 | 12,982 | [e]3,800 | [e]12,800 | 4,071 | 14,412 |
| Dimension do. | 42 | 15,794 | [e]60 | [e]18,642 | W | W |
| Combined value of beryllium, clays (bentonite), lime, mica (scrap), and values indicated by symbol W | XX | 11,432 | XX | [r]11,265 | XX | 62,772 |
| Total | XX | 222,093 | XX | [r]198,869 | XX | 207,339 |
| TENNESSEE |  |  |  |  |  |  |
| Clays thousand short tons | 1,066 | $26,516 | [r] [2]1,165 | [r] [2]$21,690 | [2]1,244 | [2]$25,913 |
| Gem stones | NA | 5 | NA | 5 | NA | 5 |
| Phosphate rock thousand metric tons | 1,193 | 29,073 | 1,368 | 33,275 | 1,233 | 27,600 |
| Sand and gravel: |  |  |  |  |  |  |
| Construction thousand short tons | [e]6,100 | [e]18,700 | 6,304 | 19,830 | [e]7,200 | [e]22,000 |
| Industrial do. | 483 | 5,455 | 650 | 6,903 | 569 | 6,156 |
| Stone: |  |  |  |  |  |  |
| Crushed do. | 30,578 | 111,573 | [e]36,200 | [e]138,000 | [e]37,939 | [e]155,760 |
| Dimension do. | 7 | 1,161 | [e]7 | [e]1,097 | 5 | 778 |
| Zinc (recoverable content of ores, etc.) metric tons | 109,958 | 100,336 | 116,526 | 124,854 | 104,471 | 92,971 |
| Combined value of barite, cement, clays (fuller's earth, 1985), copper, lead (1984-85), lime, pyrites, silver, and stone (crushed granite, 1985) | XX | 114,493 | XX | [r]131,918 | XX | 141,109 |
| Total | XX | 407,312 | XX | [r]477,572 | XX | 472,287 |
| TEXAS |  |  |  |  |  |  |
| Cement: |  |  |  |  |  |  |
| Masonry thousand short tons | 276 | $19,704 | 291 | $24,409 | 263 | $22,114 |
| Portland do. | 9,760 | 534,298 | 10,423 | 557,421 | 10,242 | 532,494 |
| Clays do. | 3,955 | 22,575 | [r] [2]3,517 | [r] [2]17,091 | 4,107 | 28,059 |
| Gem stones | NA | 225 | NA | 175 | NA | 175 |
| Gypsum thousand short tons | 2,049 | 16,357 | 2,166 | 19,431 | 1,981 | 17,299 |
| Helium (Grade-A) million cubic feet | 524 | 18,340 | W | W | W | W |
| Lime thousand short tons | 1,067 | 60,193 | 1,157 | 61,214 | 1,192 | 65,927 |
| Salt do. | 8,028 | 65,670 | 8,184 | 69,672 | 8,390 | 80,434 |
| Sand and gravel: |  |  |  |  |  |  |
| Construction do. | [e]58,500 | [e]208,000 | 62,389 | 199,461 | [e]57,800 | [e]198,000 |
| Industrial do. | 1,788 | 29,637 | 2,028 | 29,282 | 1,968 | 29,095 |
| Stone: |  |  |  |  |  |  |
| Crushed do. | 76,328 | 239,187 | [e]89,200 | [e]300,000 | 85,764 | 306,821 |
| Dimension do. | 50 | 11,071 | [e]47 | [e]11,236 | 37 | 11,760 |
| Sulfur (Frasch) thousand metric tons | 2,468 | W | 2,994 | W | 2,979 | W |
| Talc and pyrophyllite thousand short tons | 250 | 3,933 | [r]240 | [r]4,125 | 261 | 5,245 |
| Combined value of asphalt (native, 1984-85), clays (fuller's earth and kaolin, 1984), fluorspar, helium (crude), iron ore, magnesium chloride, magnesium compounds, mica (scrap, 1984-85), sodium sulfate, and values indicated by symbol W | XX | 279,291 | XX | [r]419,861 | XX | 435,936 |
| Total | XX | 1,508,481 | XX | [r]1,713,378 | XX | 1,733,359 |

See footnotes at end of table.

## Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

| Mineral | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| | | | **UTAH** | | | |
| Beryllium concentrate short tons | W | W | 6,030 | $6 | 5,738 | $6 |
| Clays thousand short tons | [2]227 | [2]$1,569 | [2]315 | [2]2,223 | 332 | 2,509 |
| Copper (recoverable content of ores, etc.) metric tons | 169,751 | 286,403 | W | W | W | W |
| Gem stones | NA | 80 | NA | 80 | NA | 80 |
| Gold (recoverable content of ores, etc.) troy ounces | 238,459 | 101,107 | W | W | 135,489 | 43,039 |
| Gypsum thousand short tons | 305 | 2,736 | 277 | 2,671 | 413 | 4,033 |
| Lime do. | 315 | 16,771 | 297 | 16,471 | 225 | 11,912 |
| Salt do. | 936 | 23,184 | 1,246 | 28,651 | 1,189 | 28,468 |
| Sand and gravel: | | | | | | |
| Construction do. | [e]9,800 | [e]19,800 | 15,217 | 34,507 | [e]14,000 | [e]36,400 |
| Industrial do. | 24 | W | 11 | W | W | W |
| Silver (recoverable content of ores, etc.) thousand troy ounces | 4,567 | 52,242 | W | W | W | W |
| Stone (crushed) thousand short tons | 4,407 | 14,636 | [e]5,200 | [e]16,400 | 4,657 | 14,180 |
| Combined value of asphalt (native), cement, clays (fuller's earth, 1983-84), iron ore (usable, 1983), lead (1984), magnesium compounds, molybdenum, perlite (1983), phosphate rock, potassium salts, sodium sulfate, stone (dimension, 1983 and 1985), vanadium (1983-84), zinc (1984), and values indicated by symbol W | XX | 138,051 | XX | [r]424,828 | XX | 171,732 |
| Total | XX | 656,579 | XX | [r]525,332 | XX | 312,359 |
| | | | **VERMONT** | | | |
| Sand and gravel (construction) thousand short tons | [e]3,000 | [e]$6,200 | 3,802 | $8,071 | [e]2,700 | [e]$7,000 |
| Stone: | | | | | | |
| Crushed do. | 1,339 | 5,579 | [e]1,800 | [e]7,000 | 1,689 | 7,468 |
| Dimension do. | 116 | 19,995 | [e]116 | [e]20,462 | 116 | 26,346 |
| Combined value of talc and other industrial minerals | XX | 10,355 | XX | 9,565 | XX | 9,040 |
| Total | XX | 42,129 | XX | 45,098 | XX | 49,854 |
| | | | **VIRGINIA** | | | |
| Clays thousand short tons | 784 | $5,467 | 712 | $6,004 | 814 | $6,977 |
| Gem stones | NA | 20 | NA | 20 | NA | 20 |
| Iron oxide pigments, crude short tons | W | W | W | W | 2,280 | W |
| Lime thousand short tons | 557 | 24,637 | 562 | 24,799 | 633 | 28,103 |
| Sand and gravel (construction) do. | [e]7,200 | [e]30,800 | 8,860 | 37,359 | [e]10,200 | [e]42,000 |
| Stone: | | | | | | |
| Crushed do. | 37,959 | 159,553 | [e]47,200 | [e]196,000 | 51,686 | 221,900 |
| Dimension do. | 93 | 2,238 | [e]22 | [e]3,052 | 10 | 3,136 |
| Combined value of aplite, cement, gypsum, kyanite, sand and gravel (industrial), talc (soapstone), vermiculite, and values indicated by symbol W | XX | 66,629 | XX | 74,355 | XX | 79,140 |
| Total | XX | 289,344 | XX | 341,589 | XX | 381,276 |
| | | | **WASHINGTON** | | | |
| Clays thousand short tons | [2]282 | [2]$1,715 | 292 | [r] [2]$1,598 | 243 | $1,402 |
| Gem stones | NA | 200 | NA | 200 | NA | 200 |
| Peat thousand short tons | W | W | W | W | 12 | 292 |
| Sand and gravel: | | | | | | |
| Construction do. | [e]15,800 | [e]50,300 | 23,369 | 61,070 | [e]22,700 | [e]62,300 |
| Industrial do. | 337 | 4,581 | 356 | 5,201 | 322 | 5,589 |
| Stone: | | | | | | |
| Crushed do. | 10,451 | 29,607 | [e]10,400 | [e]31,700 | 9,543 | 31,052 |
| Dimension do. | 1 | 37 | -- | -- | 1 | 53 |
| Combined value of barite, calcium chloride (natural, 1985), cement, clays (fire clay, 1983-84) diatomite, gold, gypsum, lime, olivine, silver, talc (1983-84), and values indicated by symbol W | XX | 101,025 | XX | [r]102,855 | XX | 142,782 |
| Total | XX | 187,465 | XX | 202,624 | XX | 243,670 |

See footnotes at end of table.

## Table 5.—Nonfuel mineral production[1] in the United States, by State —Continued

| Mineral | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| **WEST VIRGINIA** |  |  |  |  |  |  |
| Clays thousand short tons | [2]249 | [2]$532 | 381 | $3,410 | 331 | $3,342 |
| Salt do | 1,026 | W | 1,004 | W | 895 | W |
| Sand and gravel (construction) do | [e]700 | [e]3,400 | 976 | 3,198 | [e]900 | [e]3,000 |
| Stone (crushed) do | 9,439 | 37,962 | [e]9,100 | [e]37,300 | 9,393 | 38,348 |
| Combined value of cement, clays (fire clay, 1983), lime, sand and gravel (industrial), and values indicated by symbol W | XX | 62,079 | XX | 68,279 | XX | 60,719 |
| Total | XX | 103,973 | XX | 112,187 | XX | 105,409 |
| **WISCONSIN** |  |  |  |  |  |  |
| Lime thousand short tons | 319 | $17,624 | 373 | $19,892 | 341 | $19,001 |
| Peat do | 9 | W | 9 | W | 10 | W |
| Sand and gravel: |  |  |  |  |  |  |
| Construction do | [e]14,200 | [e]28,800 | 17,785 | 38,245 | [e]16,000 | [e]36,000 |
| Industrial do | 621 | 7,208 | 1,060 | 11,821 | 1,197 | 14,624 |
| Stone: |  |  |  |  |  |  |
| Crushed do | 14,252 | 39,896 | [e]15,800 | [e]45,000 | 14,496 | 42,380 |
| Dimension do | 24 | 2,884 | [e]24 | [e]2,863 | 22 | 2,733 |
| Combined value of abrasive stone, cement, and values indicated by symbol W | XX | 4,779 | XX | 11,527 | XX | 10,372 |
| Total | XX | 101,191 | XX | 129,348 | XX | 125,110 |
| **WYOMING** |  |  |  |  |  |  |
| Clays thousand short tons | 2,140 | $49,059 | [r]2,628 | [r]$67,921 | 2,302 | $64,146 |
| Gem stones | NA | 250 | NA | 225 | NA | 225 |
| Gypsum thousand short tons | 382 | 2,963 | 376 | 2,618 | 576 | 4,488 |
| Sand and gravel (construction) do | [e]2,400 | [e]8,000 | 4,586 | 13,372 | [e]3,500 | [e]11,000 |
| Stone (crushed) do | 2,019 | 7,769 | [e]1,900 | [e]7,600 | [9]2,030 | [9]7,329 |
| Combined value of beryllium concentrate (1983), cement (portland), iron ore (1983), lime, sodium carbonate, and stone (crushed granite, 1985) | XX | 561,860 | XX | 458,187 | XX | 465,275 |
| Total | XX | 629,901 | XX | [r]549,923 | XX | 552,468 |

[e]Estimated. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

[2] Excludes certain clays; value included with "Combined value" figure.

[3] Less than 1/2 unit.

[4] Partial total, excludes the values of magnesium compounds, which must be concealed to avoid disclosing company proprietary data.

[5] Excludes bentonite and fire clay.

[6] Excludes marl; value included with "Combined value" figure.

[7] Excludes salt in brines; value included with "Combined value" figure.

[8] Excludes sandstone; value included with "Combined value" figure.

[9] Excludes other stone; data included with "Combined value" figure.

[10] Excludes traprock; data included with "Combined value" figure.

## Table 6.—Mineral production[1] in the islands administered by the United States

(Thousand short tons and thousand dollars)

| Area and mineral | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value | Quantity | Value |
| American Samoa: Stone | NA | NA | NA | NA | (2) | 1 |
| Guam: Stone | 329 | 2,192 | [e]345 | [e]2,280 | 548 | 3,731 |
| Virgin Islands: Stone | 237 | 2,305 | [e]249 | [e]2,397 | 214 | 2,405 |

[e]Estimated. NA Not available.

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

[2] Less than 1/2 unit.

## Table 7.—Mineral production[1] in the Commonwealth of Puerto Rico

(Thousand short tons and thousand dollars)

| Mineral | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value | Quantity | Value |
| Cement (portland) | 931 | 82,509 | 997 | 87,568 | 962 | 72,602 |
| Clays | 125 | 251 | 128 | 266 | 118 | 264 |
| Lime | 35 | 3,885 | 35 | 4,531 | 23 | 3,249 |
| Sand and gravel | NA | NA | 43 | W | -- | -- |
| Stone: |  |  |  |  |  |  |
| Crushed | 5,536 | 26,611 | [e]5,813 | [e]27,675 | 5,493 | 25,799 |
| Dimension | W | W | [e]35 | [e]455 | -- | -- |
| Total[2] | XX | 113,256 | XX | 120,495 | XX | 101,914 |

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data; not included in "Total." XX Not applicable.

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

[2] Total does not include value of items not available or withheld.

## Table 8.—U.S. exports of principal minerals and products, excluding mineral fuels

| Mineral | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value (thousands) | Quantity | Value (thousands) |
| METALS |  |  |  |  |
| Aluminum: |  |  |  |  |
| Ingots, slabs, crude metric tons | 259,598 | $396,798 | 347,292 | $441,598 |
| Scrap do | 258,404 | 275,686 | 374,646 | 350,669 |
| Plates, sheets, bars, etc do | 198,399 | 496,841 | 167,874 | 411,337 |
| Castings and forgings do | 11,590 | 69,845 | 12,408 | 74,498 |
| Aluminum sulfate do | 2,789 | 1,185 | 5,698 | 1,178 |
| Other aluminum compounds do | 37,616 | 31,700 | 32,390 | 27,829 |
| Antimony, metals and alloys, crude short tons | 511 | 915 | 362 | 876 |
| Bauxite including bauxite concentrate thousand metric tons | 82 | 12,735 | 56 | 6,407 |
| Beryllium pounds | 39,315 | 2,562 | 119,428 | 6,375 |
| Bismuth, metals and alloys do | 311,511 | 1,091 | 268,669 | 603 |
| Cadmium metal metric tons | 106 | 208 | 86 | 342 |
| Chromium: |  |  |  |  |
| Ore and concentrate: |  |  |  |  |
| Exports thousand short tons | 55 | 2,957 | 101 | 4,600 |
| Reexports do | 4 | 864 | 4 | 670 |
| Ferrochromium do | 15 | 10,542 | 10 | 7,688 |
| Cobalt (content) thousand pounds | 670 | 7,661 | 627 | 7,355 |
| Copper: |  |  |  |  |
| Ore, concentrate, composition metal, unrefined (copper content) metric tons | 74,528 | 91,558 | 168,024 | 175,307 |
| Scrap do | 80,810 | 96,266 | 134,300 | 132,386 |
| Refined copper and semimanufactures do | 135,885 | 351,999 | 101,121 | 448,227 |
| Other copper manufactures do | 13,817 | 30,438 | 7,883 | 17,522 |
| Ferroalloys not elsewhere listed: |  |  |  |  |
| Ferrophosphorus short tons | 39,603 | 5,279 | 49,674 | 5,776 |
| Ferroalloys, n.e.c do | 27,485 | 16,158 | 14,498 | 24,581 |
| Gold: |  |  |  |  |
| Ore and base bullion troy ounces | 1,498,617 | 528,284 | 1,078,369 | 334,331 |
| Bullion, refined do | 3,482,473 | 1,284,718 | 2,888,309 | 919,433 |
| Iron ore thousand long tons | 4,993 | 239,257 | 5,033 | 240,557 |
| Iron and steel: |  |  |  |  |
| Pig iron short tons | 56,674 | 5,685 | 31,614 | 3,543 |
| Iron and steel products (major): |  |  |  |  |
| Steel mill products do | 977,284 | 904,011 | 929,954 | 855,078 |
| Other steel products do | 261,246 | 513,942 | 200,387 | 465,672 |
| Iron and steel scrap: Ferrous scrap including rerolling materials, ships, boats, other vessels for scrapping thousand short tons | 9,840 | 938,402 | 10,191 | 940,416 |
| Lead: |  |  |  |  |
| Ore and concentrate metric tons | 11,858 | 4,760 | 9,987 | 4,503 |
| Pigs, bars, anodes, sheets, etc do | 7,445 | 15,214 | 27,342 | 20,977 |
| Scrap do | 45,097 | 11,575 | 59,949 | 12,963 |
| Magnesium, metal and alloys, scrap, semimanufactured forms, n.e.c short tons | 48,337 | 136,661 | 40,322 | 113,600 |
| Manganese: |  |  |  |  |
| Ore and concentrate do | 237,606 | 15,643 | 56,040 | 4,286 |
| Ferromanganese do | 6,764 | 4,397 | 6,927 | 4,762 |
| Silicomanganese do | 5,333 | 2,237 | 3,089 | 1,359 |
| Metal do | 4,082 | 5,915 | 5,162 | 7,242 |

## Table 8.—U.S. exports of principal minerals and products, excluding mineral fuels —Continued

| Mineral | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value (thousands) | Quantity | Value (thousands) |
| METALS —Continued |  |  |  |  |
| Molybdenum: |  |  |  |  |
| Ore and concentrate (molybdenum content) thousand pounds | 63,366 | $242,770 | 63,859 | $247,690 |
| Metal and alloys, crude and scrap do | 306 | 1,209 | 574 | 2,365 |
| Wire do | 474 | 5,954 | 546 | 6,130 |
| Semimanufactured forms, n.e.c. do | 257 | 6,368 | 408 | 8,390 |
| Powder do | 461 | 3,272 | 369 | 2,298 |
| Ferromolybdenum do | 650 | 1,567 | 1,262 | 2,698 |
| Compounds do | 26,602 | 56,453 | 23,769 | 46,109 |
| Nickel:[1] |  |  |  |  |
| Primary (unwrought commercially pure, anodes, ferronickel, powder and flakes) short tons | 35,807 | 131,480 | 24,354 | 96,503 |
| Wrought (bars, rods, angles, shapes, sections; plates, sheets, strip; tubes, pipes, blanks, fittings, hollow bar; wire) do | 6,857 | 75,219 | 8,155 | 89,289 |
| Compound catalysts and waste and scrap do | 15,861 | 38,722 | 18,920 | 49,516 |
| Platinum-group metals: |  |  |  |  |
| Ore and scrap troy ounces | [r]563,345 | 123,849 | 362,384 | 76,993 |
| Palladium, rhodium, iridium, osmiridium, ruthenium, osmium (metal and alloys including scrap) do | [r]377,302 | 74,748 | 339,254 | 56,116 |
| Platinum (metal and alloys) do | 220,885 | 76,749 | 187,013 | 54,052 |
| Rare-earth metals: Ferrocerium and alloys short tons | 34 | 309 | 29 | 317 |
| Selenium kilograms | 122,929 | 1,587 | 154,122 | 1,431 |
| Silicon: |  |  |  |  |
| Ferrosilicon short tons | 29,364 | 21,135 | 12,969 | 12,671 |
| Silicon carbide, crude and in grains (including reexports) do | 6,023 | 8,613 | 5,186 | 7,446 |
| Silver: |  |  |  |  |
| Ore, concentrate, waste, sweepings thousand troy ounces | 14,108 | 119,965 | 12,145 | 79,086 |
| Bullion, refined do | 10,340 | 86,339 | 12,611 | 81,746 |
| Tantalum: |  |  |  |  |
| Ore, metal, other forms thousand pounds | 508 | 24,603 | 491 | 19,265 |
| Powder do | 151 | 17,026 | 143 | 15,188 |
| Tin: |  |  |  |  |
| Ingots, pigs, bars, etc.: Exports metric tons | 1,429 | 14,409 | 1,478 | 16,744 |
| Tinplate and terneplate do | 154,679 | 93,033 | 155,119 | 85,000 |
| Titanium: |  |  |  |  |
| Ore and concentrate short tons | 8,651 | 1,936 | 27,759 | 6,953 |
| Unwrought and scrap metal do | 4,484 | 9,359 | 6,992 | 17,475 |
| Intermediate mill shapes and mill products, n.e.c do | 2,849 | 61,502 | 3,395 | 70,423 |
| Pigments and oxides do | 108,247 | 102,828 | 103,201 | 112,870 |
| Tungsten (tungsten content): |  |  |  |  |
| Ore and concentrate metric tons | 129 | 1,240 | 124 | 831 |
| Carbide powder do | 448 | 12,415 | 661 | 15,784 |
| Alloy powder do | 816 | 17,329 | 1,449 | 33,331 |
| Vanadium: |  |  |  |  |
| Ore and concentrate (vanadium content) thousand pounds | 24 | 109 | 5 | 9 |
| Pentoxide, etc do | 7,423 | 14,514 | 3,058 | 6,300 |
| Ferrovanadium do | 938 | 5,205 | 908 | 4,791 |
| Zinc: |  |  |  |  |
| Slabs, pigs, or blocks metric tons | 760 | 975 | 1,011 | 1,525 |
| Sheets, plates, strips, other forms, n.e.c do | 975 | 2,421 | 776 | 1,973 |
| Waste, scrap, dust (zinc content) do | 42,079 | 23,871 | 45,984 | 22,080 |
| Semifabricated forms, n.e.c do | 1,428 | 2,349 | 2,674 | 3,500 |
| Ore and concentrate do | 30,579 | 13,353 | 23,264 | 8,216 |
| Zirconium: |  |  |  |  |
| Ore and concentrate short tons | 9,528 | 2,647 | 16,855 | 3,965 |
| Oxide do | 422 | 1,263 | 1,048 | 3,332 |
| Metals, alloys, other forms do | 808 | 42,523 | 1,153 | 51,558 |
| INDUSTRIAL MINERALS |  |  |  |  |
| Abrasives (includes reexports): |  |  |  |  |
| Industrial diamond, natural or synthetic: |  |  |  |  |
| Powder or dust thousand carats | 47,992 | 74,337 | 51,593 | 81,806 |
| Other do | 3,301 | 30,441 | 3,291 | 29,530 |
| Diamond grinding wheels do | 536 | 5,141 | 553 | 6,603 |
| Other natural and artificial metallic abrasives and products | XX | [2]99,719 | XX | [2]89,716 |
| Asbestos: |  |  |  |  |
| Exports: |  |  |  |  |
| Unmanufactured metric tons | 39,779 | 18,221 | 45,075 | 16,366 |
| Products | XX | 162,690 | XX | 193,476 |
| Reexports: |  |  |  |  |
| Unmanufactured metric tons | 140 | 125 | 581 | 123 |
| Products | XX | 657 | XX | 289 |
| Barite: Natural barium sulfate short tons | 1,449 | 574 | 5,876 | 692 |

See footnotes at end of table.

## Table 8.—U.S. exports of principal minerals and products, excluding mineral fuels —Continued

| Mineral | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) |
| INDUSTRIAL MINERALS —Continued | | | | |
| Boron: | | | | |
| Boric acid ______ short tons | 44,728 | $24,402 | 49,457 | $21,598 |
| Sodium borates, refined ______ do | [r]576,231 | 134,000 | 623,375 | 151,000 |
| Bromine compounds ______ thousand pounds | 53,200 | 16,200 | 61,000 | 23,400 |
| Calcium: | | | | |
| Other calcium compounds including precipitated calcium carbonate ______ short tons | 37,000 | 17,000 | 49,000 | 25,000 |
| Chloride ______ do | 34,062 | 20,568 | 26,143 | 6,343 |
| Dicalcium phosphate ______ do | 40,000 | 33,000 | 58,600 | 43,000 |
| Cement: Hydraulic and clinker ______ do | 80,007 | 13,496 | 97,897 | 21,478 |
| Clays: | | | | |
| Kaolin or china clay' ______ thousand short tons | 1,418 | 170,137 | 1,381 | 174,204 |
| Bentonite ______ do | 563 | 45,375 | 640 | 44,973 |
| Other ______ do | 718 | 80,221 | 759 | 90,694 |
| Diatomite ______ do | 127 | 29,461 | 120 | 28,519 |
| Feldspar, leucite, nepheline syenite ______ short tons | 10,080 | 920 | 9,280 | 680 |
| Fluorspar ______ do | 12,266 | 1,292 | 9,671 | 1,063 |
| Gem stones (including reexports): | | | | |
| Diamond ______ thousand carats | 2,273 | 574,719 | 2,378 | 571,300 |
| Pearls ______ | XX | 8,265 | XX | 3,600 |
| Other ______ | XX | 98,150 | XX | 56,500 |
| Graphite, natural ______ short tons | 7,096 | 2,807 | 10,159 | 3,830 |
| Gypsum: | | | | |
| Crude, crushed or calcined ______ thousand short tons | 131 | 12,711 | 83 | 13,021 |
| Manufactured, wallboard and plaster articles ______ | XX | 17,141 | XX | 13,398 |
| Helium ______ million cubic feet | 392 | 21,461 | 439 | 25,316 |
| Lime ______ short tons | 24,714 | 6,805 | 19,383 | 5,155 |
| Lithium compounds: | | | | |
| Lithium carbonate ______ thousand pounds | 18,069 | 24,487 | 13,916 | 19,006 |
| Lithium hydroxide ______ do | 8,198 | 14,108 | 7,853 | 13,709 |
| Other lithium compounds ______ do | 5,430 | .9,765 | 5,608 | 12,453 |
| Magnesium compounds: | | | | |
| Magnesite, dead-burned ______ short tons | 17,275 | 3,641 | 24,805 | 5,529 |
| Magnesite, crude, caustic-calcined, lump or ground ______ do | 32,053 | 14,026 | 21,567 | 9,773 |
| Mica: | | | | |
| Waste, scrap, ground ______ thousand pounds | 15,306 | 2,038 | 17,378 | 2,370 |
| Block, film, splittings ______ do | 348 | 549 | 82 | 159 |
| Manufactured, cut or stamped, built-up ______ do | NA | 4,519 | NA | 5,103 |
| Mineral-earth pigments, iron oxide, natural and synthetic short tons | 32,428 | 31,832 | 29,720 | 27,574 |
| Nitrogen compounds (major) ______ thousand short tons | 10,439 | 1,635,430 | 10,799 | 1,553,387 |
| Phosphate rock ______ thousand metric tons | [r]11,316 | [r]392,032 | 10,284 | 281,515 |
| Phosphatic fertilizers: | | | | |
| Phosphoric acid ______ do | [r]867 | [r]181,055 | 716 | 141,162 |
| Superphosphates ______ do | 2,847 | [r]149,150 | 5,524 | 176,515 |
| Diammonium phosphates ______ do | 6,346 | 1,200,579 | 6,131 | 1,048,322 |
| Elemental phosphorus ______ metric tons | 14,852 | 22,375 | 17,131 | 27,024 |
| Pigments and compounds: Zinc oxide (metal content) ______ do | 288 | 627 | 359 | 1,005 |
| Potash: | | | | |
| Potassium chloride ______ do | 621,820 | 57,200 | 699,770 | NA |
| Potassium sulfate ______ do | 67,320 | 13,940 | 91,000 | NA |
| Quartz, crystal: | | | | |
| Cultured ______ thousand pounds | 277 | 11,021 | 185 | 3,723 |
| Natural ______ do | 42 | 234 | 60 | 290 |
| Salt: | | | | |
| Crude and refined ______ thousand short tons | 820 | 15,299 | 904 | 15,988 |
| Shipments to noncontiguous territories ______ do | [r]18 | 2,301 | 23 | 5,196 |
| Sand and gravel: | | | | |
| Construction: | | | | |
| Sand ______ do | 1,210 | 8,094 | 997 | 6,212 |
| Gravel ______ do | 635 | 2,231 | 516 | 2,723 |
| Industrial sand ______ do | 1,193 | 27,656 | 866 | 22,580 |
| Sodium compounds: | | | | |
| Sodium carbonate ______ do | 1,648 | 160,774 | 1,771 | 186,064 |
| Sodium sulfate ______ do | 76 | 9,587 | 119 | 11,899 |
| Stone: | | | | |
| Crushed ______ do | 2,378 | 23,970 | 2,372 | 29,347 |
| Dimension ______ do | NA | [r]23,007 | NA | 13,835 |
| Sulfur, crude ______ thousand metric tons | 1,334 | 156,067 | 1,365 | 189,248 |
| Talc, crude and ground ______ thousand short tons | 256 | 16,162 | 237 | 14,282 |
| Total ______ | XX | [r]13,988,499 | XX | 13,065,121 |

[r] Revised. NA Not available. XX Not applicable.

[1] Not comparable to prior years owing to regrouping of nickel forms.

[2] Silicon carbide (crude and refined) has been deducted and is shown separately elsewhere in this table.

### Table 9.—U.S. imports for consumption of principal minerals and products, excluding mineral fuels

| Mineral | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) |
| **METALS** | | | | |
| Aluminum: | | | | |
| Metal ... metric tons | 881,956 | $1,292,724 | 868,674 | $1,017,453 |
| Scrap ... do | 137,675 | 145,748 | 127,501 | 108,625 |
| Plates, sheets, bars, etc ... do | 457,562 | 1,027,631 | 423,769 | 847,476 |
| Aluminum oxide (alumina) thousand metric tons | 4,466 | 976,364 | 3,979 | 809,664 |
| Antimony: | | | | |
| Ore and concentrate (antimony content) short tons | 4,299 | 6,798 | 6,638 | 12,381 |
| Sulfide including needle or liquated ... do | 72 | 157 | 167 | 256 |
| Metal ... do | 3,898 | 8,037 | 5,129 | 10,983 |
| Oxide ... do | 17,884 | 26,348 | 10,620 | 20,765 |
| Arsenic: | | | | |
| White ($As_2O_3$ content) ... do | 13,985 | 9,454 | 16,472 | 14,059 |
| Metallic ... do | 304 | 2,127 | 407 | 2,150 |
| Bauxite, crude ... thousand metric tons | [r]10,228 | NA | 7,944 | NA |
| Beryllium ore ... short tons | 1,332 | 1,177 | 1,646 | 1,427 |
| Bismuth, metals and alloys (gross weight) ... pounds | 1,948,394 | 5,892 | 1,998,865 | 10,172 |
| Cadmium metal ... metric tons | 1,889 | 5,133 | 1,988 | 4,122 |
| Calcium metal ... pounds | 248,973 | 670 | 492,244 | 1,395 |
| Cesium compounds and chloride ... do | 53,652 | 1,552 | 50,537 | 1,595 |
| Chromium: | | | | |
| Ore and concentrate ($Cr_2O_3$ content) thousand short tons | 134 | 15,477 | 176 | 20,170 |
| Ferrochromium (gross weight) ... do | 426 | 183,451 | 331 | 156,546 |
| Ferrochromium-silicon ... do | 8 | 3,736 | 4 | 2,085 |
| Metal ... do | 5 | 24,073 | 4 | 19,615 |
| Cobalt: | | | | |
| Metal ... thousand pounds | 23,316 | 202,954 | 16,613 | 181,379 |
| Oxide (gross weight) ... do | 706 | 5,285 | 246 | 2,258 |
| Salts and compounds (gross weight) ... do | 2,284 | 5,371 | 1,413 | 4,431 |
| Columbium ore ... do | 3,265 | 6,030 | 2,899 | 4,673 |
| Copper (copper content): | | | | |
| Ore and concentrate ... metric tons | 11,056 | 9,863 | 2,869 | 1,739 |
| Matte ... do | 2,094 | 2,586 | 3,997 | 6,997 |
| Blister ... do | 38,949 | 52,950 | 12,979 | 15,529 |
| Refined in ingots, etc ... do | 444,699 | 620,674 | 377,725 | 491,798 |
| Scrap ... do | 23,005 | 28,925 | 23,014 | 25,680 |
| Ferroalloys not elsewhere listed, including spiegeleisen short tons | 5,321 | 27,304 | 5,225 | 25,969 |
| Gallium ... kilograms | 9,669 | 4,050 | 7,961 | 3,447 |
| Germanium ... do | 116,719 | 7,539 | 14,841 | 8,829 |
| Gold: | | | | |
| Ore and base bullion ... troy ounces | 1,837,052 | 653,307 | 1,865,022 | 587,002 |
| Bullion, refined ... do | 6,031,550 | 2,293,606 | 6,360,977 | 2,109,475 |
| Hafnium ... short tons | 1 | 115 | 1 | 185 |
| Indium ... thousand troy ounces | 1,022 | 4,577 | 980 | 3,480 |
| Iron ore ... thousand long tons | 17,187 | 529,065 | 15,771 | 452,240 |
| Iron and steel: | | | | |
| Pig iron ... short tons | 702,355 | 83,985 | 338,258 | 50,619 |
| Iron and steel products (major): | | | | |
| Steel mill products ... do | [r]26,169,048 | [r]10,201,074 | 24,278,482 | 9,565,642 |
| Other products ... do | [r]1,146,133 | [r]1,155,386 | 1,211,146 | 1,308,921 |
| Scrap including tinplate ... thousand short tons | 572 | 46,946 | 601 | 45,620 |
| Lead: | | | | |
| Ore, flue dust, matte (lead content) ... metric tons | 29,888 | 11,923 | 2,649 | 979 |
| Base bullion (lead content) ... do | 43 | 57 | 760 | 398 |
| Pigs and bars (lead content) ... do | 161,489 | 86,189 | 131,353 | 53,864 |
| Reclaimed scrap, etc. (lead content) ... do | 5,026 | 2,029 | 3,168 | 1,212 |
| Sheets, pipes, shot ... do | 1,667 | 4,044 | 1,981 | 2,517 |
| Magnesium: | | | | |
| Metal and scrap ... short tons | 5,296 | 12,260 | 4,866 | 10,303 |
| Alloys (magnesium content) ... do | 3,596 | 10,791 | 3,651 | 12,774 |
| Sheets, tubing, ribbons, wire, other forms (magnesium content) ... do | 489 | 2,620 | 754 | 2,010 |
| Manganese: | | | | |
| Ore (35% or more contained manganese) ... do | 338,094 | 16,024 | 386,859 | 22,561 |
| Ferromanganese ... do | 409,310 | 117,678 | 366,874 | 104,389 |
| Ferrosilicon-manganese (manganese content) do | 91,339 | 44,746 | 109,719 | 51,423 |
| Metal ... do | 13,314 | 12,978 | 8,566 | 9,052 |
| Mercury: | | | | |
| Compounds ... pounds | [r]249,083 | [r]1,111 | 329,889 | 1,625 |
| Metal ... 76-pound flasks | 25,327 | 7,274 | 18,890 | 5,337 |

See footnotes at end of table.

### Table 9.—U.S. imports for consumption of principal minerals and products, excluding mineral fuels —Continued

| Mineral | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) |
| METALS —Continued | | | | |
| Molybdenum: | | | | |
| Ore and concentrate (molybdenum content) thousand pounds | 28 | $183 | 112 | $566 |
| Waste and scrap (gross weight) do | NA | 2,565 | NA | 2,830 |
| Metal: | | | | |
| Unwrought (molybdenum content) do | 142 | 2,170 | 145 | 2,370 |
| Wrought (gross weight) do | 132 | 3,023 | 94 | 2,301 |
| Ferromolybdenum (gross weight) do | 2,086 | 4,438 | 1,424 | 3,721 |
| Material in chief value molybdenum (molybdenum content) do | 5,266 | 19,441 | 2,239 | 7,329 |
| Compounds (gross weight) do | 3,437 | 6,251 | 3,815 | 6,678 |
| Nickel: | | | | |
| Pigs, ingots, shot, cathodes short tons | 103,017 | 461,371 | 97,779 | 446,009 |
| Plates, bars, etc do | 8,650 | 58,120 | 10,100 | 89,660 |
| Slurry do | 82,509 | 116,956 | 68,210 | 101,101 |
| Scrap do | 6,199 | 20,542 | 5,552 | 16,430 |
| Powder and flakes do | 15,829 | 78,736 | 12,753 | 67,717 |
| Ferronickel do | 43,048 | 68,429 | 36,528 | 60,258 |
| Oxide do | 5,526 | 22,413 | 5,079 | 20,722 |
| Platinum-group metals: | | | | |
| Unwrought: | | | | |
| Grains and nuggets (platinum) troy ounces | 19,786 | 5,647 | 20,827 | 6,807 |
| Sponge (platinum) do | 1,527,841 | 617,888 | 1,464,645 | 542,183 |
| Sweepings, waste, scrap do | 526,738 | 61,920 | 530,724 | 62,342 |
| Iridium do | 18,225 | 7,472 | 20,972 | 9,615 |
| Palladium do | 1,795,989 | 278,222 | 1,396,810 | 174,333 |
| Rhodium do | 155,671 | 83,979 | 201,028 | 173,310 |
| Ruthenium do | 198,257 | 16,652 | 162,887 | 16,474 |
| Other platinum-group metals do | 10,602 | 3,796 | 15,701 | 4,707 |
| Semimanufactured: | | | | |
| Platinum do | 60,140 | 22,682 | 78,206 | 23,946 |
| Palladium do | 158,012 | 24,192 | 84,492 | 9,532 |
| Rhodium do | 2,389 | 516 | 145 | 78 |
| Other platinum-group metals do | 506 | 122 | 13,157 | 2,422 |
| Rare-earth metals: | | | | |
| Ferrocerium and other cerium alloys kilograms | 138,128 | 1,651 | 113,385 | 1,302 |
| Monazite metric tons | 5,661 | 2,202 | 5,694 | 1,984 |
| Metals including scandium and yttrium kilograms | 4,316 | 619 | 3,185 | 285 |
| Rhenium: | | | | |
| Metal including scrap pounds | 1,962 | 450 | 4,943 | 1,225 |
| Ammonium perrhenate (rhenium content) do | r4,754 | 1,052 | 3,325 | 669 |
| Selenium and selenium compounds (selenium content) kilograms | 376,946 | 8,054 | 400,658 | 8,358 |
| Silicon: | | | | |
| Metal (over 96% silicon content) short tons | 25,221 | 55,381 | 51,801 | 83,367 |
| Ferrosilicon do | 143,651 | 72,874 | 155,421 | 74,019 |
| Silver: | | | | |
| Ore and base bullion thousand troy ounces | 13,018 | 105,587 | 3,533 | 20,180 |
| Bullion, refined do | 93,546 | 784,838 | 137,398 | 855,550 |
| Sweepings, waste, doré do | 8,402 | 72,772 | 11,671 | 76,218 |
| Tantalum ore thousand pounds | 2,199 | 19,054 | 787 | 8,187 |
| Tellurium (tellurium content) kilograms | r35,333 | 725 | 30,050 | 871 |
| Thallium pounds | 2,964 | 96 | 2,655 | 50 |
| Tin: | | | | |
| Concentrate (tin content) metric tons | 3,272 | 20,862 | 1,636 | 10,659 |
| Dross, skimmings, scrap, residue, tin alloys, n.s.p.f. do | 1,211 | 1,318 | 877 | 2,804 |
| Tinfoil, powder, flitters, etc | XX | 3,292 | XX | 3,290 |
| Tin compounds metric tons | 838 | 5,301 | 827 | 5,164 |
| Titanium: | | | | |
| Ilmenite[1] short tons | 619,444 | 43,846 | 798,632 | 66,821 |
| Rutile do | 180,508 | 44,910 | 179,663 | 43,967 |
| Metal do | 5,533 | 35,469 | 5,479 | 39,408 |
| Ferrotitanium and ferrosilicon titanium do | 579 | 861 | 483 | 982 |
| Pigments do | 193,501 | 186,952 | 196,213 | 206,809 |
| Tungsten ore and concentrate (tungsten content) metric tons | 5,807 | 51,715 | 4,746 | 36,706 |
| Vanadium (vanadium content): | | | | |
| Ferrovanadium thousand pounds | 2,341 | 11,839 | 1,557 | 7,757 |
| Pentoxide do | 297 | 1,269 | 22 | 180 |
| Vanadium-bearing materials do | 1,266 | 552 | 605 | 535 |
| Zinc: | | | | |
| Ore (zinc content) metric tons | 86,172 | 29,186 | 90,186 | 33,626 |
| Blocks, pigs, slabs do | 639,228 | 635,940 | 610,900 | 508,008 |
| Sheets, etc do | 850 | 1,308 | 3,559 | 2,757 |
| Fume (zinc content) do | 314 | 171 | -- | -- |
| Waste and scrap do | 6,259 | 3,940 | 3,247 | 1,848 |
| Dross and skimmings do | 5,027 | 3,161 | 4,942 | 2,419 |
| Dust, powder, flakes do | 7,572 | 9,505 | 8,681 | 10,781 |
| Manufactured | XX | 927 | XX | 713 |

See footnotes at end of table.

## Table 9.—U.S. imports for consumption of principal minerals and products, excluding mineral fuels —Continued

| Mineral | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) |
| METALS —Continued | | | | |
| Zirconium: | | | | |
| Ore including zirconium sand short tons | 66,436 | $7,548 | 43,787 | $4,599 |
| Metal, scrap, compounds do | 1,844 | 20,330 | 4,202 | 24,962 |
| INDUSTRIAL MINERALS | | | | |
| Abrasives: | | | | |
| Diamond (industrial) thousand carats | 43,710 | 113,632 | 46,222 | 127,191 |
| Other | XX | 268,062 | XX | 255,686 |
| Asbestos metric tons | 209,963 | 64,749 | 142,431 | 44,093 |
| Barite: | | | | |
| Crude and ground thousand short tons | 1,776 | 74,945 | 2,127 | 82,913 |
| Witherite short tons | 226 | 153 | 142 | 74 |
| Chemicals do | 35,208 | 20,524 | 32,907 | 19,978 |
| Boron: | | | | |
| Boric acid (contained boron oxide) do | [r]4,000 | 3,449 | 6,000 | 5,121 |
| Colemanite (contained boron oxide) thousand short tons | 20,000 | 12,123 | 33,000 | 24,620 |
| Ulexite do | 47,000 | 10,202 | 31,000 | 11,120 |
| Bromine (contained in compounds) thousand pounds | 16,080 | 10,996 | 17,079 | 11,065 |
| Calcium chloride short tons | 22,078 | 1,817 | 77,736 | 10,967 |
| Cement: Hydraulic and clinker thousand short tons | 8,846 | [r]294,207 | 14,487 | 437,429 |
| Clays short tons | 31,585 | 4,868 | 40,902 | 5,981 |
| Cryolite do | 22,722 | 13,124 | 16,596 | 10,003 |
| Feldspar: | | | | |
| Crude do | 2 | 1 | 936 | 1,126 |
| Ground and crushed do | 23 | 14 | 16 | 25 |
| Fluorspar do | 703,711 | 65,241 | 552,959 | 49,639 |
| Gem stones: | | | | |
| Diamond thousand carats | [r]8,228 | 2,905,317 | 8,151 | 3,006,762 |
| Emeralds do | 4,410 | 154,644 | 2,741 | 139,000 |
| Other | XX | 591,555 | XX | 534,113 |
| Graphite, natural short tons | 58,246 | 14,579 | 52,737 | 16,186 |
| Gypsum: | | | | |
| Crude, ground, calcined thousand short tons | 8,915 | 74,357 | 9,924 | 64,331 |
| Manufactured | XX | 95,310 | XX | 91,091 |
| Iodine, crude thousand pounds | 5,067 | [r]24,803 | 4,971 | 26,761 |
| Lime: | | | | |
| Hydrated short tons | 59,906 | 3,669 | 48,827 | 3,407 |
| Other do | 187,579 | 9,722 | 145,230 | 8,810 |
| Lithium: | | | | |
| Ore do | [r]150 | [r]33 | 4,716 | 1,277 |
| Compounds do | 462 | 2,313 | 1,402 | 5,774 |
| Magnesium compounds: | | | | |
| Crude magnesite do | [r]758 | 232 | 1,350 | 332 |
| Lump or ground caustic-calcined magnesia do | [r]54,893 | 9,594 | 65,709 | 10,407 |
| Refractory magnesia, dead-burned, fused magnesite, dead-burned dolomite do | 155,162 | [r]26,186 | 179,207 | 32,075 |
| Compounds do | 46,153 | 10,036 | 36,751 | 10,085 |
| Mica: | | | | |
| Waste, scrap, ground thousand pounds | 23,198 | 3,251 | 20,057 | 2,920 |
| Block, film, splittings do | 1,480 | 644 | 1,684 | 1,080 |
| Manufactured, cut or stamped, built-up do | 856 | 2,836 | 978 | 3,154 |
| Mineral-earth pigments, iron oxide: | | | | |
| Ocher, crude and refined short tons | 7 | 31 | 26 | 22 |
| Siennas, crude and refined do | 160 | 72 | 270 | 49 |
| Umber, crude and refined do | 6,401 | 1,012 | 4,921 | 795 |
| Vandyke brown do | 659 | 244 | 404 | 140 |
| Other natural and refined do | 996 | 444 | 1,026 | 561 |
| Synthetic do | 30,015 | 19,720 | 33,151 | 20,999 |
| Nepheline syenite: | | | | |
| Crude do | 410 | 17 | 920 | 62 |
| Ground, crushed, etc do | 377,535 | 14,201 | 331,684 | 11,373 |
| Nitrogen compounds (major) including urea thousand short tons | 8,476 | 984,524 | 8,544 | 880,348 |
| Peat: | | | | |
| Fertilizer-grade short tons | 453,387 | 53,491 | 452,018 | 54,244 |
| Poultry- and stable-grade do | 31,685 | 4,318 | 25,370 | 3,606 |
| Phosphates, crude and apatite thousand metric tons | 9 | 274 | 34 | 1,593 |
| Phosphatic fertilizers: | | | | |
| Fertilizer and fertilizer materials do | 119 | 7,536 | 30 | 5,929 |
| Elemental phosphorus do | [r]4 | 6,482 | 2 | 3,530 |
| Other do | 11 | 1,550 | 3 | 492 |

See footnotes at end of table.

## Table 9.—U.S. imports for consumption of principal minerals and products, excluding mineral fuels —Continued

| Mineral | 1984 Quantity | 1984 Value (thousands) | 1985 Quantity | 1985 Value (thousands) |
|---|---|---|---|---|
| INDUSTRIAL MINERALS —Continued | | | | |
| Pigments and salts: | | | | |
| Lead pigments and compounds metric tons | 19,081 | $15,022 | 16,272 | $12,468 |
| Zinc pigments and compounds do. | 52,432 | 48,178 | 52,310 | 48,244 |
| Potash do. | 7,947,700 | 658,100 | 7,570,900 | 499,100 |
| Pumice: | | | | |
| Crude or unmanufactured short tons | 16,703 | 402 | 781 | 198 |
| Wholly or partly manufactured do. | [r]192 | [r]48 | 357 | 103 |
| Manufactured, n.s.p.f | XX | 148 | XX | 218 |
| Quartz crystal (Brazilian lascas) thousand pounds | 569 | 373 | 173 | 99 |
| Salt thousand short tons | 7,545 | 74,100 | 6,207 | 65,593 |
| Sand and gravel: | | | | |
| Industrial sand do. | 26 | 926 | 81 | 1,513 |
| Other sand and gravel do. | 151 | 1,603 | 246 | 1,572 |
| Sodium compounds: | | | | |
| Sodium carbonate do. | 17 | 2,301 | 56 | 8,089 |
| Sodium sulfate do. | 265 | 21,198 | 194 | 14,492 |
| Stone: | | | | |
| Crushed do. | 2,923 | 15,071 | 2,725 | 10,209 |
| Dimension | XX | [r]223,150 | XX | 295,094 |
| Calcium carbonate fines thousand short tons | 292 | 2,471 | 281 | 1,432 |
| Strontium: | | | | |
| Minerals short tons | 48,852 | 4,293 | 37,552 | 3,321 |
| Compounds do. | 4,755 | 3,386 | 7,403 | 5,586 |
| Sulfur and compounds, sulfur ore and other forms, n.e.s thousand metric tons | [r]2,557 | [r]200,189 | 2,104 | 199,240 |
| Talc, unmanufactured thousand short tons | 45 | 9,156 | 47 | 9,532 |
| Total | XX | [r]31,497,367 | XX | 29,450,174 |

[r]Revised. NA Not available. XX Not applicable.

[1]Includes titanium slag averaging about 70% $TiO_2$. For details, see "Titanium" chapter.

## Table 10.—Comparison of world and U.S. production of selected nonfuel mineral commodities

(Thousand short tons unless otherwise specified)

| Mineral | 1984 World production[1] | 1984 U.S. production | 1984 U.S. percent of world production | 1985[p] World production[1] | 1985[p] U.S. production | 1985[p] U.S. percent of world production |
|---|---|---|---|---|---|---|
| METALS, MINE BASIS | | | | | | |
| Antimony (content of ore and concentrate) short tons | 60,396 | 557 | 1 | 60,621 | W | NA |
| Arsenic trioxide[2] metric tons | 44,099 | 6,800 | 15 | 45,030 | 2,200 | 5 |
| Bauxite[3] thousand metric tons | 88,173 | 856 | 1 | 85,133 | 674 | 1 |
| Beryl short tons | 9,838 | 6,030 | 61 | 9,688 | 5,738 | 59 |
| Bismuth thousand pounds | 8,415 | W | NA | 9,175 | W | NA |
| Chromite | 10,312 | -- | -- | 10,951 | -- | -- |
| Cobalt (content of ore and concentrate) short tons | 35,869 | -- | -- | 39,867 | -- | -- |
| Columbium-tantalum concentrate (gross weight) thousand pounds | 78,827 | -- | -- | 83,857 | -- | -- |
| Copper (content of ore and concentrate) thousand metric tons | 7,986 | 1,103 | 14 | 8,114 | 1,106 | 14 |
| Gold (content of ore and concentrate) thousand troy ounces | 46,408 | 2,085 | 4 | 48,217 | 2,475 | 5 |
| Iron ore (gross weight) thousand long tons | 817,428 | 51,269 | 6 | 845,251 | 48,751 | 6 |
| Lead (content of ore and concentrate) thousand metric tons | 3,256 | 334 | 10 | 3,392 | 424 | 12 |
| Manganese ore gross weight) | 26,027 | -- | -- | 26,922 | -- | -- |
| Mercury thousand 76-pound flasks | 195 | 19 | 10 | 196 | 17 | 9 |
| Molybdenum (content of ore and concentrate) thousand pounds | 214,506 | 103,664 | 48 | 215,139 | 108,409 | 50 |
| Nickel (content of ore and concentrate) | 833 | 15 | 2 | 857 | 6 | 1 |
| Platinum-group metals[2] thousand troy ounces | 7,648 | 15 | ([4]) | 7,951 | W | NA |

See footnotes at end of table.

## Table 10.—Comparison of world and U.S. production of selected nonfuel mineral commodities —Continued

(Thousand short tons unless otherwise specified)

| Mineral | 1984 | | | 1985[p] | | |
|---|---|---|---|---|---|---|
| | World production[1] | U.S. production | U.S. percent of world production | World production[1] | U.S. production | U.S. percent of world production |
| **METALS, MINE BASIS —Continued** | | | | | | |
| Silver (content of ore and concentrate) thousand troy ounces | 415,239 | 44,592 | 11 | 412,273 | 39,357 | 10 |
| Tin (content of ore and concentrate) metric tons | 198,432 | W | NA | 191,103 | W | NA |
| Titanium concentrates (gross weight): | | | | | | |
| Ilmenite | 3,402 | W | NA | 3,654 | W | NA |
| Rutile | 388 | W | NA | 402 | W | NA |
| Tungsten ore and concentrate (contained tungsten) metric tons | 46,478 | 1,203 | 3 | 46,989 | 996 | 2 |
| Vanadium (content of ore and concentrate) short tons | 34,291 | 1,617 | 5 | 33,665 | W | NA |
| Zinc (content of ore and concentrate) thousand metric tons | 6,564 | 278 | 4 | 6,676 | 252 | 4 |
| **METALS, SMELTER BASIS** | | | | | | |
| Aluminum (primary only) do | 15,664 | 4,099 | 26 | 15,289 | 3,500 | 23 |
| Cadmium metric tons | 19,171 | 1,686 | 9 | 18,662 | 1,603 | 9 |
| Cobalt short tons | 25,608 | -- | -- | 28,217 | -- | -- |
| Copper smelter (primary and secondary)[5] thousand metric tons | 8,344 | 1,183 | 14 | 8,331 | 1,138 | 14 |
| Iron, pig | 546,317 | 51,961 | 10 | 555,222 | 49,963 | 9 |
| Lead, smelter (primary and secondary)[6] thousand metric tons | 5,494 | 1,072 | 20 | 5,569 | 1,124 | 20 |
| Magnesium (primary) | 360 | 159 | 44 | 361 | 150 | 42 |
| Nickel[7] | 771 | 45 | 6 | 782 | 36 | 5 |
| Selenium[8] kilograms | 1,350,702 | 253,598 | 19 | 1,122,835 | W | NA |
| Steel, raw | 782,008 | [9]92,528 | 12 | 788,119 | [9]88,259 | 11 |
| Tellurium[8] kilograms | 99,594 | W | NA | 98,500 | W | NA |
| Tin metric tons | 199,669 | [10]4,000 | 2 | 193,715 | [10]3,000 | 2 |
| Zinc (primary and secondary) thousand metric tons | 6,463 | 331 | 5 | 6,567 | 312 | 5 |
| **INDUSTRIAL MINERALS** | | | | | | |
| Asbestos do | 4,106 | 57 | 1 | 4,111 | 57 | 1 |
| Barite | 6,352 | [11]775 | 12 | 6,671 | [11]739 | 11 |
| Boron minerals | 2,775 | 1,367 | 49 | 2,679 | 1,269 | 47 |
| Bromine thousand pounds | 873,550 | [11]385,000 | 44 | 835,090 | [11]320,000 | 38 |
| Cement, hydraulic | 1,045,468 | [12]78,699 | 8 | 1,071,225 | [12]78,859 | 7 |
| Clays: | | | | | | |
| Bentonite[8] | 6,493 | [11]3,438 | 53 | 6,245 | [11]3,195 | 51 |
| Fuller's earth[8] | 2,528 | [11]1,899 | 75 | 2,704 | [11]2,059 | 76 |
| Kaolin[8] | 23,354 | [11]7,953 | 34 | 23,361 | [11]7,793 | 33 |
| Corundum short tons | 16,265 | -- | -- | 16,805 | -- | -- |
| Diamond thousand carats | 63,517 | -- | -- | 66,371 | -- | -- |
| Diatomite | 1,933 | 627 | 32 | 1,951 | 635 | 33 |
| Feldspar | 4,167 | 710 | 17 | 4,294 | 700 | 16 |
| Fluorspar | 5,270 | 72 | 1 | 5,268 | 66 | 1 |
| Graphite short tons | 685,507 | W | NA | 676,740 | W | NA |
| Gypsum | 86,767 | 14,319 | 17 | 89,220 | 14,726 | 17 |
| Iodine, crude thousand pounds | 27,419 | W | NA | 27,141 | W | NA |
| Lime | 125,630 | [11] [12]15,956 | 13 | 123,531 | [11] [12]15,718 | 13 |
| Magnesite | 13,121 | W | NA | 13,208 | W | NA |
| Mica (including scrap and ground) thousand pounds | 608,700 | 322,000 | 53 | 537,792 | 275,100 | 51 |
| Nitrogen, N content of ammonia | 93,029 | 13,368 | 14 | 94,302 | 13,238 | 14 |
| Peat | 282,719 | 800 | (4) | 283,106 | 839 | (4) |
| Perlite | 1,808 | [11]498 | 28 | 1,798 | [11]507 | 28 |
| Phosphate rock (gross weight) thousand metric tons | 152,488 | 49,197 | 32 | 151,363 | 50,835 | 34 |
| Potash ($K_2O$ equivalent) do | 29,348 | 1,564 | 5 | 28,618 | 1,296 | 5 |
| Pumice[8] | 12,662 | [11]502 | 4 | 12,110 | [11]508 | 4 |
| Salt | 188,699 | [11] [12]39,256 | 21 | 187,693 | [11] [12]39,519 | 21 |

See footnotes at end of table.

### Table 10.—Comparison of world and U.S. production of selected nonfuel mineral commodities —Continued

(Thousand short tons unless otherwise specified)

| Mineral | 1984 | | | 1985[p] | | |
|---|---|---|---|---|---|---|
| | World production[1] | U.S. production | U.S. percent of world production | World production[1] | U.S. production | U.S. percent of world production |
| INDUSTRIAL MINERALS —Continued | | | | | | |
| Sodium compounds, natural and manufactured: | | | | | | |
| Sodium carbonate | 31,126 | 8,511 | 27 | 31,628 | 8,597 | 27 |
| Sodium sulfate | 4,697 | 872 | 19 | 4,647 | 827 | 18 |
| Strontium[8] short tons | 137,236 | -- | -- | 138,700 | -- | -- |
| Sulfur, all forms thousand metric tons | 52,607 | 10,652 | 20 | 54,856 | 11,609 | 21 |
| Talc and pyrophyllite | 8,351 | 1,127 | 14 | 8,305 | 1,269 | 15 |
| Vermiculite[8] | 545 | 315 | 58 | 556 | 314 | 56 |

[p] Preliminary. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1] For those commodities for which U.S. data are withheld to avoid disclosing company proprietary data, the world total excludes U.S. output and the U.S. percent of world production cannot be reported.

[2] World total does not include an estimate for output in China.

[3] U.S. figures represent dried bauxite equivalent of crude ore; to the extent possible, individual country figures that are included in the world total are also on the dried bauxite equivalent basis, but for some countries, available data are insufficient to permit this adjustment.

[4] Less than 0.5%.

[5] Primary and secondary blister and anode copper, including electrowon refined copper that is not included as blister or anode.

[6] Includes bullion.

[7] Refined nickel plus nickel content of ferronickel, and nickel oxide.

[8] World total does not include estimates for output in the U.S.S.R. or China.

[9] Data from American Iron and Steel Institute. Excludes production of castings by companies that do not report steel ingot.

[10] Includes tin content of alloys made directly from ore.

[11] Quantity sold or used by producers.

[12] Includes Puerto Rico.

# Abrasive Materials

### By Bureau of Mines Staff

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The combined production value of natural abrasives, which consist of tripoli, special silica stone, garnet, and emery, decreased in 1985. Shipments of processed tripoli increased slightly in quantity but decreased 6% in value. Production of garnet, an abundant iron-aluminum silicate, increased 24% in quantity and 20% in value. There was an 11% increase in the quantity and a 7% increase in the value of refined garnet shipped when compared with 1984 shipments, a new record high. Production of crude special silica stone decreased 10% in quantity and 14% in value, and shipments of finished special silica stone products decreased 35% in quantity and 63% in value. Both the quantity and value of special silica stone finished products sold or used were the lowest since 1981. Production of emery, an impure aluminum oxide, decreased 56% in quantity and 61% in value of product mined and shipped.

**Table 1.—Salient U.S. abrasives statistics**

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Natural abrasives production by producers: | | | | | |
| Tripoli (crude) short tons | 107,330 | 112,928 | 111,020 | 124,482 | W |
| Value thousands | $617 | $653 | $649 | $699 | W |
| Special silica stone[1] short tons | 2,501 | 1,285 | 1,101 | 1,290 | 1,157 |
| Value thousands | $1,096 | $553 | $482 | $602 | $515 |
| Garnet[2] short tons | 25,451 | 27,303 | 29,767 | 29,647 | 36,727 |
| Value thousands | $2,059 | $2,321 | $2,533 | $2,487 | $2,978 |
| Emery short tons | W | W | W | W | W |
| Value thousands | W | W | W | W | W |
| Manufactured abrasives[3] short tons | [4]586,915 | 418,224 | [4]418,158 | [4]531,264 | [4]478,897 |
| Value thousands | [4]$225,503 | $167,471 | [4]$167,430 | [4]$203,231 | [4]$171,974 |
| Foreign trade (natural and artificial abrasives): | | | | | |
| Exports (value) do | $189,719 | $174,126 | $192,794 | $191,003 | $191,272 |
| Reexports (value) do | $27,758 | $22,650 | $24,111 | $27,248 | $23,845 |
| Imports for consumption (value) do | $301,695 | $245,048 | $289,865 | $381,694 | $382,877 |

W Withheld to avoid disclosing company proprietary data.

[1] Includes grindstones, oilstones, and whetstones. Excludes grinding pebbles and tube-mill liners.

[2] Primary garnet; denotes first marketable product.

[3] Includes Canadian production of crude silicon carbide and fused aluminum oxide and shipments of metallic abrasives by producers.

[4] Excludes U.S. and Canadian production and value of aluminum-zirconium oxide.

The nonmetallic manufactured abrasives industry, which consisted of crude silicon carbide and fused aluminum oxide, experienced a 10% decrease in shipments and a 20% decrease in value. The average unit values of these shipments, including high-purity fused aluminum oxide, dropped from those of 1984.

The metallic abrasives industry, which consisted of primary producers of steel, chilled and annealed shot and grit, plus cut wire shot manufacturers, reported a 9% decrease in quantity and an 8% decrease in value shipped from those of 1984 shipments.

U.S. exports of diamond grit and powder reached a new record high at 50 million carats, a 5% increase over 1984 exports.

Total imports of abrasive materials increased slightly in value. Imports of industrial diamond increased 6% in value and 12% in quantity. Imported stone increased 14% in quantity and 21% in value with an average price of $8.52 per carat, a 6% increase from that of 1984. Imports of synthetic grit, powder, and dust from Ireland increased slightly in quantity but accounted for 75% of the imports in this category. The average value of the synthetic grit, powder, and dust imported from Ireland increased from $1.44 to $1.49 per carat. Total exports plus reexports of abrasive materials decreased slightly in value.

**Domestic Data Coverage.**—Domestic production data for abrasive materials are developed by the Bureau of Mines from six separate, voluntary surveys. Of the 51 operations canvassed, producing natural and manufactured abrasives, all responded, representing 100% of the total production shown in tables 1, 5, 6, 8, 15, 16, and 17.

## FOREIGN TRADE

Exports plus reexports of industrial diamonds, loose, increased 7% in volume to 54.9 million carats, and 6% in value to $111.3 million. This was a record high quantity. The diamond content in diamond wheels, exported and reexported, was 553,000 carats, a slight increase; the declared value was $6.6 million, an increase of 28.4%. The value of imported diamond wheels increased 28% to $10.5 million.

The value of imported abrasive materials was essentially unchanged from that of 1984, and exports plus reexports decreased slightly in value. Net imports were valued at $167.8 million.

### Table 2.—U.S. exports of abrasive materials, by kind

(Thousands)

| Kind | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| NATURAL ABRASIVES | | | | |
| Industrial diamond, natural or synthetic, powder or dust _ carats__ | 47,213 | $72,484 | 49,725 | $78,235 |
| Industrial diamond, natural or synthetic, other do____ | 859 | 6,626 | 1,556 | 10,227 |
| Emery, natural corundum, pumice in blocks pounds__ | 3,783 | 947 | 1,918 | 833 |
| MANUFACTURED ABRASIVES | | | | |
| Artificial corundum (fused aluminum oxide) do____ | 24,588 | 15,329 | 24,531 | 15,004 |
| Silicon carbide, crude or in grains do____ | 11,365 | 8,086 | 10,004 | 7,147 |
| Carbide abrasives, n.e.c do____ | 911 | 1,250 | 1,420 | 1,005 |
| Other refined abrasives do____ | 29,939 | 17,078 | 21,152 | 12,364 |
| Grinding and polishing wheels and stones: | | | | |
| Diamond carats__ | 532 | 5,085 | 552 | 6,544 |
| Polishing stones, whetstones, oilstones, hones, similar stone number__ | 827 | 2,360 | 726 | 2,208 |
| Wheels and stones, n.e.c pounds__ | 3,465 | 20,171 | 3,445 | 19,343 |
| Abrasive paper and cloth, coated with natural or artificial abrasive materials do____ | 11,915 | 36,045 | 10,405 | 33,576 |
| Grit and shot including wire pellets do____ | 18,313 | 5,542 | 16,172 | 4,786 |
| Total | XX | 191,003 | XX | 191,272 |

XX Not applicable.

## Table 3.—U.S. reexports of abrasive materials, by kind

(Thousands)

| Kind | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value |
| NATURAL ABRASIVES |  |  |  |  |
| Industrial diamond, natural or synthetic, powder or dust carats | 779 | $1,853 | 1,868 | $3,571 |
| Industrial diamond, natural or synthetic, other do. | 2,442 | 23,815 | 1,735 | 19,303 |
| Emery, natural corundum, pumice in blocks pounds | 227 | 230 | 30 | 13 |
| MANUFACTURED ABRASIVES |  |  |  |  |
| Artificial corundum (fused aluminum oxide) do. | 282 | 126 | 57 | 40 |
| Silicon carbide, crude or in grains do. | 680 | 527 | 367 | 299 |
| Carbide abrasives, n.e.c. do. | 10 | 71 | -- | -- |
| Grinding and polishing wheels and stones: |  |  |  |  |
| Diamond carats | 4 | 56 | 1 | 59 |
| Polishing stones, whetstones, oilstones, hones, similar stone number | -- | -- | 7 | 16 |
| Wheels and stones, n.e.c pounds | 32 | 200 | 55 | 266 |
| Abrasive paper and cloth, coated with natural or artificial abrasive materials do. | 109 | 370 | 45 | 278 |
| Total | XX | 27,248 | XX | 23,845 |

XX Not applicable.

## Table 4.—U.S. imports for consumption of abrasive materials (natural and artificial), by kind

(Thousands)

| Kind | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value |
| Emery, flint, rottenstone, tripoli, crude or crushed short tons | 20 | $421 | 24 | $475 |
| Silicon carbide, crude do. | 64 | 29,992 | 56 | 22,854 |
| Aluminum oxide, crude do. | 175 | 75,755 | 152 | 60,444 |
| Other crude artificial abrasives do. | 8 | 3,513 | 14 | 4,570 |
| Abrasives, ground, grains, pulverized or refined: |  |  |  |  |
| Rottenstone and tripoli do. | -- | -- | -- | -- |
| Silicon carbide do. | 7 | 9,343 | 6 | 9,007 |
| Aluminum oxide do. | 21 | 17,140 | 18 | 13,982 |
| Emery, corundum, flint, garnet, other, including artificial abrasives do. | 3 | 5,475 | 2 | 5,343 |
| Papers, cloths, other materials wholly or partly coated with natural or artificial abrasives | (1) | 71,525 | (1) | 78,219 |
| Hones, whetstones, oilstones, polishing stones number | 2,191 | 1,154 | 7,102 | 1,757 |
| Abrasive wheels and millstones: |  |  |  |  |
| Burrstones manufactured or bound up into millstones short tons | (2) | 49 | (2) | 14 |
| Solid natural stone wheels number | 291 | 165 | 429 | 300 |
| Diamond do. | 229 | 8,207 | 420 | 10,477 |
| Abrasive wheels bonded with resins pounds | 9,662 | 16,469 | 11,208 | 16,891 |
| Other | (1) | 12,313 | (1) | 16,299 |
| Articles not specifically provided for: |  |  |  |  |
| Emery or garnet | (1) | 250 | (1) | 554 |
| Natural corundum or artificial abrasive materials | (1) | 8,886 | (1) | 8,367 |
| Other n.s.p.f | (1) | 4,494 | (1) | 4,094 |
| Grit and shot, including wire pellets pounds | 18,759 | 2,385 | 6,757 | 1,478 |
| Diamond, natural and synthetic: |  |  |  |  |
| Diamond dies number | 12 | 526 | 14 | 561 |
| Crushing bort carats | 219 | 291 | 390 | 568 |
| Natural industrial diamond stones do. | 7,125 | 58,838 | 8,174 | 74,433 |
| Miners' diamond do. | [3]1,157 | 7,690 | [3]1,271 | 6,019 |
| Powder and dust, synthetic do. | 28,381 | 38,684 | 29,633 | 38,860 |
| Powder and dust, natural do. | 6,828 | 8,129 | 6,754 | 7,311 |
| Total | XX | 381,694 | XX | 382,877 |

XX Not applicable.

[1] Quantity not reported.

[2] Less than 1/2 unit.

[3] Includes 43,000 carats of synthetic miners' diamond in 1984 and 111,000 carats in 1985.

Industrial diamond imports totaled 46.2 million carats of loose material valued at $127.2 million, an increase of 6% in quantity and 12% in value. Imports of synthetic powder and dust increased to 29.6 million carats with an average value of $1.31 per carat compared with 28.4 million carats at $1.36 per carat in 1984. Imports from Ireland increased 3% in this category and accounted for 46% of the synthetic powder and dust increase. Industrial diamond stone imports increased 1.2 million carats, while the value increased $0.49 per carat to $8.52. Ireland, the largest U.S. source of industrial diamonds in terms of quantity, shipped to the United States a total of 25.8 million carats, mostly synthetic, valued at $43.1 million. Although the quantity increased slightly, the value increased 8%, primarily because of increases in the unit prices of all categories except miners' diamond. Of the 25.8 million carats from Ireland, 22.3 million carats was synthetic powder and dust with an average value of $1.49 per carat. The share of imports of industrial diamond from Ireland was 56% of total quantity and 34% of total value.

The Republic of South Africa, the largest U.S. source of imported industrial diamonds in terms of value, shipped to the United States a total of 4.7 million carats valued at $45.9 million, a decrease of 41% in quantity and 8% in value. The share of imports from the Republic of South Africa was 10% of the total quantity and 36% of the total value. Of the 4.7 million carats, 3.9 million carats were industrial stones with an average value of $11.49 per carat, a 47% increase from that of 1984.

## TRIPOLI

Fine-grained, porous silica materials are grouped together under the category tripoli because they have similar properties and end uses. Processed tripoli, sold or used, increased slightly in quantity and decreased slightly in value; most of the increase in quantity was for filler material, and the value decreases occurred in both abrasive and filler end uses.

Because tripoli grains lack distinct edges and corners, they were used as mild abrasives in toothpaste and industrial soaps and as buffing and polishing compounds in lacquer finishing in the automobile industry. The mineral was also used as a filler and extender in paint, plastic, rubber, and enamels.

The five tripoli producers were Malvern Minerals Co., Garland County, AR, which produced crude and finished material; American Tripoli Co., which produced crude material in Ottawa County, OK, and finished material in Newton County, MO; Illinois Minerals Co. and Tammsco Inc., both in Alexander County, IL, which produced crude and finished amorphous (microcrystalline) silica; and Keystone Filler and Manufacturing Co., in Northumberland County, PA, which processed rottenstone, a decomposed fine-grained siliceous limestone or shale.

Prices quoted in the Engineering and Mining Journal, December 1985, for tripoli and amorphous silica were as follows:

| | |
|---|---|
| Tripoli, paper bags, carload lots, f.o.b., in cents per pound: | |
| White, Elco, IL: Air floated through 200 mesh | 3.55 |
| Rose and cream, Seneca, MO, and Rogers, AR: | |
| Once ground | 2.90 |
| Double ground | 2.90 |
| Air float | 3.15 |
| Amorphous silica, 50-pound, paper bags, f.o.b. Elco, IL, in dollars per ton: | |
| Through 200 mesh, 90% to 95% | $71.00 |
| Through 200 mesh, 96% to 99% | 72.00 |
| Through 325 mesh, 90% to 95% | 73.00 |
| Through 325 mesh, 96% to 98% | 69.50 |
| Through 325 mesh, 98% to 99.4% | 78.00 |
| Through 325 mesh, 99.5% | 95.00 |
| Through 400 mesh, 99.9% | 128.00 |
| Below 15 micrometers, 99% | 137.00 |
| Below 10 micrometers, 99% | 164.00 |
| Below 8 micrometers, 99% | 196.00 |

### Table 5.—Processed tripoli[1] sold or used by producers in the United States, by use[2]

| Use | | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|
| Abrasives | short tons | 34,494 | 35,798 | 38,073 | 40,812 | 40,022 |
| Value | thousands | $2,206 | $2,477 | $3,203 | $3,738 | $3,670 |
| Filler | short tons | 56,932 | 55,314 | 65,138 | 65,941 | 68,800 |
| Value | thousands | $4,393 | $4,557 | $6,077 | $6,989 | $6,452 |
| Total | short tons | 91,426 | [3]91,111 | 103,211 | 106,753 | 108,822 |
| Total value | thousands | [3]$6,600 | $7,034 | $9,280 | $10,727 | $10,122 |

[1] Includes amorphous silica and Pennsylvania rottenstone.
[2] Partly estimated.
[3] Data do not add to total shown because of independent rounding.

## SPECIAL SILICA STONE PRODUCTS

Production of special silica stone products included oilstones and whetstones from Arkansas and Indiana, grindstones from Ohio, and deburring media from Wisconsin.

Four main grades of whetstones were produced, ranging from the high-quality Arkansas Stone, with porosity of 0.07% and characterized by a waxy luster, down to Washita Stone, with a porosity of 16% and resembling unglazed porcelain. The four main types were as follows:

| Trade name | Use |
|---|---|
| Washita Stone | Rapid sharpening. |
| Soft Arkansas Stone | General purpose. |
| Hard Arkansas Stone | Polishing blades to a very fine edge. |
| Black Hard Arkansas Stone | Polishing the most perfect edge possible. |

### Table 6.—Special silica stone finished products sold or used in the United States[1]

| Year | Quantity (short tons) | Value (thousands) |
|---|---|---|
| 1981 | 523 | $3,928 |
| 1982 | 713 | 5,360 |
| 1983 | 602 | 3,814 |
| 1984 | 683 | 3,975 |
| 1985 | 443 | 1,452 |

[1] Includes grindstones, oilstones, and whetstones. Excludes grinding pebbles and tube-mill liners.

### Table 7.—Producers of special silica stone products in 1985

| Company and location | Type of operation | Product |
|---|---|---|
| Arkansas Oilstone Co.: Hot Springs, AR | Stone cutting and finishing | Whetstones and oilstones. |
| Arkansas Whetstone Co. Inc.: | | |
| Hot Springs, AR | do | Do. |
| Do | Quarry | Crude novaculite. |
| Baraboo Quartzite Co. Inc.: | | |
| Baraboo, WI | Crushing and sizing | Deburring media. |
| Do | Quarry | Crude silica stone. |
| Buffalo Stone Corp.: Hot Springs, AR | Tumbling and sizing novaculite. | Metal finishing media and deburring media. |
| Cleveland Quarries Co.: | | |
| Amherst, OH | Stone cutting and finishing | Grindstones. |
| Do | Quarry | Crude silica stone. |
| Dans Whetstone Cutting Co. Inc.: | | |
| Royal, AR | Stone cutting and finishing | Whetstones and oilstones. |
| Do | Quarry | Crude novaculite. |
| Halls Arkansas Oilstones Inc.: Pearcy, AR | Stone cutting and finishing | Whetstones and oilstones. |
| Hindostan Whetstone Co.: | | |
| Bedford, IN | do | Cuticle stones. |
| Do | Quarry | Crude silica stone. |
| Hiram A. Smith Whetstone Co. Inc.: | | |
| Hot Springs, AR | Stone cutting and finishing | Whetstones and oilstones. |
| Do | Quarry | Crude novaculite. |
| Norton Co. Oilstones, Norton Pike Div.: | | |
| Hot Springs, AR | do | Do. |
| Littleton, NH | Stone cutting and finishing | Whetstones and oilstones. |
| Pioneer Whetstone Co.: Hot Springs, AR | do | Do. |
| Poor Boy Whetstones: Hot Springs, AR (inactive) | do | Do. |
| Wallis Whetstone Inc.: | | |
| Malvern, AR | do | Do. |
| Malvern, AR (inactive) | Quarry | Crude novaculite. |
| Washita Mountain Whetstone Co.: Lake Hamilton, AR | Stone cutting and finishing | Whetstones and oilstones. |

Arkansas finished stone production accounted for 78% of both the total value and the total quantity of special stone products sold or used by U.S. producers.

American Trails Whetstone Co., Glenwood, AR, and Poor Boy Whetstones, Hot Springs, AR, remained idle for the second year. Arkansas Oilstone Co., Hot Springs, AR, reported no mining activity but continued production with purchased raw materials.

## GARNET

The United States continued to account for an estimated 70% of the world's garnet production; the remainder was produced primarily, in order of size, by India, Australia, China, and the U.S.S.R. Three domestic producers continued to be active, one each in New York, Idaho, and Maine. Barton Mines Corp., Warren County, NY, sold garnet for use in coated abrasives, glass grinding and polishing, and metal lapping. The NYCO Div. of Processed Minerals Inc., Essex County, NY, reported that its byproduct garnet was not recovered in 1985. Emerald Creek Garnet Milling Co. operated two mines in Benewah County, ID, and reported that its garnet was used chiefly in sandblasting and water filtration. Industrial Garnet Extractives Inc. (IGE), near Rangeley in Oxford County, ME, produced almandine garnet and a garnet-containing utility grit concentrate which was used largely in sandblasting and water filtration. The firm doubled its mine capacity by upgrading classification facilities and making additional processing changes. These improvements parallel an improved market demand, especially for sandblasting and water filtration. In addition, IGE installed two new dust collectors at its mine operation.

Production of garnet increased 24% in quantity and 20% in value. There was a significant increase in the quantity and value of refined garnet shipped when compared with that of 1984.

**Table 8.—Garnet sold or used by producers in the United States**

| Year | Quantity (short tons) | Value (thousands) |
|---|---|---|
| 1981 | 25,519 | $5,204 |
| 1982 | 26,660 | 5,549 |
| 1983 | 30,300 | 5,970 |
| 1984 | 27,672 | 5,677 |
| 1985 | 30,634 | 6,102 |

## CORUNDUM AND EMERY

**Corundum.**—There were no imports of abrasive-grade corundum during 1981-85. Demand was met by withdrawal from stocks. In recent years, the domestic supply had consisted almost entirely of material imported from Zimbabwe through the Republic of South Africa by one firm in Massachusetts. Another Massachusetts firm accounted for one-half of the total domestic consumption. Corundum was used in grinding and polishing optical components.

**Table 9.—Natural corundum: World production, by country**[1]

(Short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| India | 1,424 | 1,494 | 787 | 487 | 550 |
| South Africa, Republic of | 100 | 68 | 54 | 23 | [2]11 |
| U.S.S.R.[e] | 9,500 | 9,500 | 9,600 | 9,600 | 9,600 |
| Uruguay[e] | 240 | 50 | 55 | 55 | 44 |
| Zimbabwe | 13,450 | 9,606 | 5,644 | [r] [e]6,100 | 6,600 |
| Total | 24,714 | 20,718 | 16,140 | 16,265 | 16,805 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through June 24, 1986.

[2] Reported figure.

**Emery.**—One company, John Leardi Emery Mine, continued to operate an emery mine near Peekskill in Westchester County, NY. The crude material, a corundum-containing silicate rock, was processed by two companies—Washington Mills Abrasives Co., North Grafton, MA, and Emeri-Crete Inc., New Castle, NH. Domestic emery was used as a nonslip additive for floors, pavements, and stair treads.

World production of emery was principally from Greece and Turkey. In 1984, production of emery in Greece was reported to be 8,929 short tons, and production in Turkey was reported to be 22,074 tons.

## INDUSTRIAL DIAMOND

Domestic production of synthetic industrial diamond was estimated to be 76 million carats, the same as in 1984. The five companies producing synthetic diamond in the United States were E. I. du Pont de Nemours & Co. Inc., Industrial Diamond Div., Gibbstown, NJ; General Electric Co., Specialty Materials Department, Worthington, OH; Megadiamond Industries Inc., Provo, UT; U.S. Synthetics Corp., Orem, UT; and Valdiamant International, a division of Valeron Corp., Ann Arbor, MI. Secondary production of industrial diamond, as salvage from used diamond tools and from wet and dry diamond-containing waste, was estimated to be 1.5 million carats.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the guidelines, industrial diamond stone would be only in tier II with a goal of 7.9 million carats. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

The U.S. Government industrial diamond stockpile inventory, as of December 31, was at 22.0 million carats of crushing bort; however, the 12.5 million carats of stone exceeded the current goal for stone of 7.7 million carats. Available for disposal, from enabling legislation effective October 1, 1984, was 5.0 million carats of stone. The inventory of small diamond dies was 25,473 pieces, compared with a goal of 60,000 pieces; however, no purchase authorization has been issued.

The United States remained the largest consumer of natural industrial diamond stones but was totally dependent on foreign sources, importing approximately 9.4 million carats.

Exports plus reexports of industrial diamond dust and powder, including synthetics, was at a record high level for quantity of 51.6 million carats valued at $81.8 million. Exports plus reexports of stone totaled 3.3 million carats valued at $29.5 million.

**Table 10.—U.S. imports for consumption of industrial diamond (excluding diamond dies)**

(Thousand carats and thousand dollars)

| Year | Quantity | Value |
|---|---|---|
| 1983 | 24,877 | 88,617 |
| 1984 | 43,710 | 113,632 |
| 1985 | 46,222 | 127,191 |

## Table 11.—U.S. imports for consumption of industrial diamond, by country[1]

(Thousand carats and thousand dollars)

| Country | Natural industrial diamond stones (including glazers' and engravers' diamond, unset) | | | | Miners' diamond[2] | | | | Powder and dust, synthetic | | | | Powder and dust, natural | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1984 | | 1985 | | 1984 | | 1985 | | 1984 | | 1985 | | 1984 | | 1985 | |
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| Australia | 2 | 61 | 1 | 24 | -- | -- | -- | -- | 1 | 3 | -- | -- | -- | -- | -- | -- |
| Belgium-Luxembourg | 159 | 2,571 | 726 | 13,808 | 6 | 86 | 200 | 102 | 227 | 170 | 723 | 151 | 576 | 383 | 572 | 411 |
| Canada | 54 | 36 | 144 | 255 | (3) | 7 | (3) | 4 | 23 | 21 | 119 | 58 | 214 | 84 | 976 | 250 |
| China | (3) | 7 | -- | -- | 1 | 4 | -- | -- | 5 | 18 | 4 | 7 | -- | -- | 22 | 11 |
| Congo | 194 | 3,918 | 14 | 277 | -- | -- | -- | -- | -- | -- | -- | -- | 32 | 108 | -- | -- |
| Finland | -- | -- | -- | -- | -- | -- | -- | -- | 118 | 110 | -- | -- | -- | -- | -- | -- |
| France | (3) | 19 | 1 | 51 | -- | -- | -- | -- | -- | -- | 94 | 45 | 3 | 2 | -- | -- |
| Germany, Federal Republic of | 38 | 1,298 | 2 | 98 | 13 | 88 | (3) | 121 | 398 | 1,069 | 579 | 887 | 38 | 74 | 70 | 83 |
| Ghana | (3) | 7 | -- | -- | 1 | 10 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Greece | 2 | 5 | -- | -- | -- | -- | -- | -- | 702 | 426 | 676 | 333 | -- | -- | -- | -- |
| Hong Kong | 2 | 5 | 9 | 77 | -- | -- | -- | -- | -- | -- | 18 | 8 | (3) | 1 | -- | -- |
| Ireland | 113 | 218 | 763 | 1,622 | 1,015 | 5,823 | 941 | 4,952 | 21,766 | 31,446 | 22,348 | 33,380 | 2,684 | 2,553 | 1,702 | 3,152 |
| Israel | 14 | 49 | 11 | 672 | -- | -- | (3) | 3 | 7 | 19 | 15 | 52 | 16 | 25 | 90 | 30 |
| Japan | 8 | 276 | 18 | 616 | 1 | 4 | -- | -- | 3,040 | 2,263 | 2,800 | 1,604 | 14 | 63 | 158 | 128 |
| Mexico | -- | -- | -- | -- | 5 | 24 | 5 | 43 | 43 | 19 | -- | -- | 6 | 6 | -- | -- |
| Netherlands | 41 | 526 | 94 | 1,487 | 20 | 20 | 6 | 97 | 4 | 19 | (3) | 22 | 86 | 45 | 8 | 8 |
| South Africa, Republic of | 5,849 | 45,877 | 3,881 | 44,594 | (3) | 24 | 1 | 42 | 433 | 977 | 49 | 59 | 1,601 | 2,888 | 749 | 1,162 |
| Switzerland | 6 | 17 | 7 | 261 | (3) | 60 | (3) | 116 | 345 | 285 | 341 | 532 | 692 | 827 | 784 | 528 |
| U.S.S.R | (3) | 30 | -- | -- | -- | -- | -- | -- | 73 | 18 | -- | -- | 351 | 116 | 442 | 130 |
| United Kingdom | 534 | 1,591 | 2,417 | 8,168 | 13 | 83 | 81 | 129 | 743 | 1,251 | 1,583 | 1,297 | 292 | 390 | 445 | 352 |
| Venezuela | 30 | 1,262 | 37 | 1,142 | (3) | 58 | 3 | 134 | -- | -- | -- | -- | -- | -- | -- | -- |
| Zaire | 36 | 54 | -- | -- | 22 | 118 | 7 | 43 | 51 | 137 | -- | 5 | 167 | 400 | 583 | 890 |
| Other Africa, n.e.c | 40 | 941 | 8 | 314 | 2 | 54 | (3) | 3 | -- | -- | -- | -- | 8 | 12 | -- | -- |
| Other | 3 | 71 | 40 | 966 | 57 | 1,227 | 26 | 230 | 404 | 434 | 289 | 420 | 48 | 153 | 152 | 177 |
| Total[4] | 7,125 | 58,838 | 8,174 | 74,433 | 1,157 | 7,690 | 1,271 | 6,019 | 28,381 | 38,684 | 29,638 | 38,860 | 6,828 | 8,129 | 6,754 | 7,311 |

[1] Excludes 219,300 carats of crushing bort from France, Japan, and the United Kingdom in 1984, and 390,400 carats from Belgium-Luxembourg, Canada, Japan, the Republic of South Africa, and the United Kingdom in 1985.

[2] Includes 43,000 carats of synthetic miners' diamond in 1984 and 111,000 carats in 1985.

[3] Less than 1/2 unit.

[4] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

De Beers Consolidated Mines Ltd.'s sales in 1985 through the Central Selling Organization were estimated to be $1.8 billion compared with $1.61 billion in 1984. Sales during the second half of 1985 were unusually strong.

**Australia.**—Argyle Diamond Mines Joint Venture produced a total of about 17 million carats from its alluvial operation before the operation was closed in October. The second phase, production from the AK-1 kimberlite pipe, commenced on schedule in December. The firm estimated that the AK-1 deposit would produce about 25 million carats per year for about 20 years.[1]

**Botswana.**—The new Jwaneng Mine expanded its diamond production. Although mining was centerod in the middle lobe, stripping proceeded on the northeastern lobe. The ore grade increased by 23% at the Jwaneng Mine, by 30% at the Letlhakane Mine, and by 8% at the Orapa Mine.

**Brazil.**—Mineração Tejucana S.A., a member of the Union Minière Group, planned an expansion of its current annual output of industrial diamonds from 52,100 carats to 62,500 carats. Coupled with an increase to 540 carats per year of industrial diamonds at the Morro Vermelho plant, Brazilian output of industrial diamonds was anticipated to increase by 10,900 carats.[2]

**Burma.**—The Ministry of Mines carried out exploration for diamonds by test pitting and drilling. It discovered 68 diamonds with a total weight of 65.31 carats in the period April 1, 1984, to December 31, 1984, mostly industrial diamonds.

**Japan.**—DEBID (BVI) Ltd. of the British Virgin Islands was reported to have taken a 95% share of the new Japanese company, Debius Industrial Diamond Japan Co.[3] The new company was to deal exclusively with the inspection and sale of imported natural and *synthetic* industrial diamonds in Japan.

**South Africa, Republic of.**—The Minister of Finance announced a special temporary surcharge of 5% over and above the 20% surcharge already in effect on taxes paid by all domestic diamond and gold mines. The new surcharge was added in view of mining profits obtained owing to the favorable rand-dollar exchange rate in 1984. The Chamber of Mines, a mining trade association, responded by saying that any additional profits had been absorbed by increased capital expenditure.

De Beers reported about 95% of 1985 South African diamond production, or about 9.7 million carats. Its Finsch Mine, the largest diamond mine in the Republic of South Africa, produced 4.9 million carats, and its Premier Mine produced 2.7 million carats. Other sources indicate that in 1984, 73% of South African production was from Cape Province, 26% from Transvaal, and the balance from the Orange Free State.

The Finsch Mine worked slightly lower grade ore, in accordance with management's plan. The Premier Mine experienced no further collapse of the gabbro sill. Investigations indicated that retreatment of the mine's stored tailings appeared to be feasible, and the processing was scheduled to begin during the year.

**Swaziland.**—Trans-Hex Ltd. was involved with its joint venture partner, the Swaziland Government, in a $5 million expansion of mining activity at its kimberlite pipe. The open pit extraction of industrial and low-quality gem diamonds, plus smaller amounts of good-quality gems, was expected to last at least 8 years. The expansion in capacity was expected to go on-stream in October 1985.

**Zaire.**—Société Minière de Bakwanga (MIBA) produced 6,896,000 carats in 1984, and exported 6,902,000 carats worth $57.9 million. MIBA invested $9.7 million in a new hydroelectric power station plus additional funds for geological exploration and research, modernization of workers' housing, and improving the security of the operations.

## Table 12.—Diamond (natural): World production, by country and type[1]

(Thousand carats)

| Country | 1981 |  |  | 1982 |  |  | 1983 |  |  | 1984[p] |  |  | 1985[e] |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Gem | Industrial | Total | Gem | Industrial | Total | Gem | Industrial | Total | Gem[2] | Industrial | Total | Gem[2] | Industrial | Total |
| Angola | 1,050 | 350 | 1,400 | 915 | 310 | 1,225 | 775 | 259 | 1,034 | [r] [e]750 | [r] [e]250 | [e]1,000 | 375 | 250 | 625 |
| Australia | 21 | 184 | 205 | [r]274 | [r]183 | [r]457 | 3,720 | 2,480 | 6,200 | 3,414 | 2,276 | 5,690 | [3]4,235 | [3]2,824 | [3]7,059 |
| Botswana | 744 | 4,217 | 4,961 | 1,165 | 6,604 | 7,769 | 4,829 | 5,902 | 10,731 | 5,810 | 7,104 | 12,914 | 5,800 | 7,100 | 12,900 |
| Brazil[4] | 163 | 926 | 1,089 | 80 | 450 | 530 | 80 | 450 | 530 | 200 | 550 | 750 | 200 | 800 | 1,000 |
| Central African Republic | 209 | 103 | 312 | 186 | 91 | 277 | 230 | 65 | 295 | 236 | 101 | 337 | 236 | 101 | 337 |
| China[e] | 190 | 760 | 950 | 200 | 800 | 1,000 | 200 | 800 | 1,000 | 200 | 800 | 1,000 | 200 | 800 | 1,000 |
| Ghana | 85 | 751 | 836 | 68 | 616 | 684 | 34 | 306 | 340 | 35 | 315 | [e]350 | 65 | 585 | 650 |
| Guinea[e] | 12 | 26 | 38 | 13 | 27 | 40 | 23 | 17 | 40 | 34 | 14 | 48 | 105 | 7 | [3]112 |
| Guyana[e] | 4 | 6 | 10 | [r]4 | [r]7 | 11 | 5 | [r]5 | [r]10 | [r]6 | [r]8 | [r]14 | 4 | 7 | 11 |
| India | 14 | 2 | 16 | 11 | 2 | 13 | 12 | 2 | 14 | 13 | 2 | 15 | 14 | 2 | 16 |
| Indonesia[e] | 3 | 12 | 15 | 3 | 12 | 15 | 5 | 22 | 27 | 5 | 22 | 27 | 5 | 22 | 27 |
| Lesotho | 49 | 4 | 53 | 39 | 3 | 42 | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Liberia | 132 | 204 | 336 | 170 | 263 | 433 | 132 | 198 | 330 | 108 | 132 | 240 | 108 | 132 | 240 |
| Namibia | 1,186 | 62 | 1,248 | 963 | 51 | 1,014 | 915 | 48 | 963 | 884 | 46 | 930 | 894 | 47 | 941 |
| Sierra Leone | 208 | 97 | 305 | 203 | 87 | 290 | 242 | 103 | 345 | 240 | 105 | [e]345 | 240 | 105 | 345 |
| South Africa, Republic of: |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Finsch Mine | 1,002 | 3,463 | 4,465 | 847 | 3,003 | 3,850 | 1,765 | 3,278 | 5,043 | 1,714 | 3,184 | 4,898 | 1,770 | 3,184 | [3]4,954 |
| Premier Mine | 510 | 1,530 | 2,040 | 615 | 1,845 | 2,460 | 800 | 1,844 | 2,644 | 765 | 1,785 | 2,550 | 820 | 1,864 | [3]2,684 |
| Other De Beers properties[4] | 1,603 | 1,069 | 2,672 | 1,359 | 906 | 2,265 | 1,400 | 569 | 1,969 | 1,452 | 593 | 2,045 | 1,500 | 569 | [3]2,069 |
| Other | 314 | 35 | 349 | 521 | 58 | 579 | 589 | 66 | 655 | 585 | 65 | 650 | 460 | 35 | 495 |
| Total | 3,429 | 6,097 | 9,526 | 3,342 | 5,812 | 9,154 | 4,554 | 5,757 | 10,311 | 4,516 | 5,627 | 10,143 | 4,550 | 5,652 | [3]10,202 |
| Swaziland | --- | --- | --- | --- | --- | --- | --- | --- | --- | 7 | 10 | 17 | 10 | 15 | 25 |
| Tanzania | 110 | 107 | 217 | 100 | 120 | 220 | 183 | 78 | 261 | 186 | 80 | 266 | 186 | 80 | 266 |
| U.S.S.R.[e] | 2,100 | 8,500 | 10,600 | 2,100 | 8,500 | 10,600 | 3,700 | 7,000 | 10,700 | 4,300 | 6,400 | 10,700 | 4,400 | 6,400 | 10,800 |
| Venezuela | 102 | 388 | 490 | 99 | 394 | [e]493 | 45 | 234 | 279 | 40 | 232 | 272 | 35 | 163 | 198 |
| Zaire | [r]360 | [r]6,801 | [r]7,161 | [r] [e]308 | [r] [e]5,856 | [r] [e]6,164 | 3,355 | 8,627 | 11,982 | 5,169 | 13,290 | 18,459 | 5,493 | 14,124 | 19,617 |
| World total | [r]10,171 | [r]29,597 | [r]39,768 | [r]10,243 | [r]30,188 | [r]40,431 | 23,039 | 32,353 | 55,392 | 26,153 | 37,364 | 63,517 | 27,155 | 39,216 | 66,371 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Table includes data available through June 3, 1986. Total diamond output (gem plus industrial) for each country is actually reported except where indicated by a footnote to be estimated. In contrast, the detailed separate production data for gem diamond and industrial diamond are Bureau of Mines estimates in the case of every country except Australia (1981-85), the Central African Republic (1981, 1983, 1984, 1985), Guinea (1984), Liberia (1981, 1984), Sierra Leone (1981), and Venezuela (1981), for which source publications give details on grade as well as totals. The estimated distribution of total output between gem and industrial diamond is conjectural and, for most countries, is based on the best available data at time of publication.

[2] Includes near-gem and cheap-gem qualities.

[3] Reported figure.

[4] Other De Beers Group output from the Republic of South Africa includes Kimberley Pool, Koffiefontein Mine, and the Namaqualand Mines.

### TECHNOLOGY

A Japanese firm developed a process for mass producing large size industrial-grade diamonds. Graphite material was subjected to pressures of 50,000 to 60,000 atmospheres and temperatures of 1,400° to 1,600° C for 100 hours. Diamonds with diameters of 6 millimeters were produced in a single cycle. Current mass production techniques were limited to the synthesis of diamonds with diameters no larger than 0.8 millimeter.[4]

A British company developed new furnace techniques, which improved general production and permitted the introduction of new drill bit matrices. These improvements were accomplished through the use of a special atmospherically controlled ceramic-tube radiant furnace. Diamond grit drill bits produced using this technique reportedly outperformed previous designs drilling hard-rock formations.[5]

## MANUFACTURED ABRASIVES

Superior Graphite Co. began production of ceramic grades of beta-silicon carbide at its facility in Hopkinsville, KY. A continuous, proprietary high-temperature processing technology is being employed that produces a free-flowing inexpensive grain that can be used as is or can be further processed to finer grits. Silicon carbide is currently made by batch processes and pulverized to meet abrasive, metallurgical, or refractory industry specification. The main markets targeted for the new line of silicon carbide are the newly emerging high-tech ceramic and advanced refractories fields. In the United Kingdom, TAC Engineering Materials, a subsidiary of Turner and Newell Ltd., established a research and development unit for engineering small production runs and prototypes using sintered silicon nitrides and selected oxide ceramics at Trafford Park, Manchester, England.[6] The company was aiming for markets in the metal extrusion, welding, textile, automotive, and other related industries.

In mergers, closures, and acquisition, Norton Canada Inc., Hamilton, Ontario, Canada, and Carborundum Abrasives Inc. have agreed in principle for Norton Canada to acquire and operate the coated abrasives business of Carborundum Abrasives Canada's Sand Papers Div. in Plattsville, Ontario, Canada. The agreement also included a provision for Norton Canada to produce and market Carborundum's bonded abrasives line.[7] Satellite Alloy Corp., a U.S. producer of silicon carbide, closed its Springfield, PA, production facility in March. The plant was sold and dismantled.

### TECHNOLOGY

A technical article encompassing a wide range of fused materials employed in abrasives, refractories, and foundry markets was published.[8] The article highlighted the international fused aluminum oxide industry with special emphasis on the North American producers. The industry production and processing flowsheets were discussed in detail along with the physical chemistry of the fusion reactions required to produce high-quality white and brown fused aluminum oxides. The paper also featured the individual company operations and the marketing areas served. The scientific rationale for the use of sintered alpha-silicon carbide (SASiC) as an advanced material for the chemical processing industries was postulated.[9] The physical, mechanical, and corrosion-resisting properties of SASiC along with high-density and high-temperature performance were compared with those of conventional alloy and ceramics and shown to be superior. Special features of the article were the tables comparing the corrosion resistance of selected materials in liquid media with SASiC and another table listing the range of uses for SASiC in six industries: oil and gas production, chemical processing, papermaking, heat treating and furnacing steel, nuclear, and mining and mineral processing. The latter table also lists the environments to be expected, the primary benefits to be derived, and processing applications.

Several noteworthy techniques and products were announced for the rapidly growing advanced ceramics and/or high-tech material fields that are silicon carbide and nitride related. De Beers Industrial Diamond Ltd. reported that cubic boron nitride, harder than either cemented carbides or ceramics, was being successfully used in machining where diamond tooling is precluded because of the reaction between the tool and the workpiece.[10] In another development, silicon carbide and nitride components, formed by hot isostatic pressing, tested favorably when compared with typical cast metal products.[11] If continuing research proves equally successful on improving high-temperature fabrication techniques, it could result in material with sufficient strength to justify use in turbine blades. A joint study by Kubota and the

Agency for Industrial Science (Japan) has resulted in a unique silicon nitride which is stronger at elevated temperatures (above 1,000° C) than at ambient temperatures.[12] The successful transfer of this physical property to a polycrystalline fabricated part could accelerate the development of high-performance ceramic motors and turbine blades. Rare earth oxides, such as lanthanum and praeseodymium, reportedly are used as the sintering additives. Lastly, a new technique was advanced for "welding" ceramic materials.[13] Initial research and development studies centered on silicon carbide and nitride ceramics.

The proprietary joining process employs an adhesive material sandwiched between the ceramic faces and then rapidly fused together electrically into a monolithic shape. By altering the composition of the special adhesive material, most ceramic materials should be amenable to this forming technique. The successful development of this method should lead to a wide variety of intricate and inexpensive ceramic components for both traditional and high-tech uses.

A West German firm developed a fully automated three-station precision honing machine which employs a single-stick bronze-bonded cubic boron nitride tooled honing facility for hydraulic boring. The machine averaged 35 seconds per bore in a cast iron valve block for bores 50 millimeters in diameter and 100 millimeters long.[14]

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[1] Industrial Minerals (London). World of Minerals. No. 220, Jan. 1986, p. 8.

[2] ———. Company News and Mineral Notes. No. 213, June 1985, p. 72.

[3] ———. Company News and Mineral Notes. No. 219, Dec. 1985, p. 91.

[4] ———. Synthetic Diamond Breakthrough. No. 213, June 1985, p. 10.

[5] ———. New Craelius KS and KM Diamond Impregnated Diamond Bits. No. 215, Aug. 1985, p. 67.

[6] ———. Company News and Mineral Notes. No. 218, Nov. 1985, p. 81.

[7] Brick and Clay Record. Refractories News—Norton Canada Buys Carborundum Abrasives. V. 187, No. 5, Nov. 1985, p. 18.

[8] Power, T. Fused Minerals—the High Purity High Performance Oxides. Ind. Miner. (London), No. 214, July 1985, pp. 37-57.

[9] Lashway, R. W. Sintered Alpha-Silicon Carbide: An Advanced Material for CPI Applications. Chem. Eng., v. 92, No. 25, Dec. 1985, pp. 121-122.

[10] Industrial Minerals (London). Company News and Mineral Notes. No. 214, July 1985, p. 76.

[11] ———. Company News and Mineral Notes. No. 213, June 1985, p. 79.

[12] ———. Company News and Mineral Notes. No. 213, June 1985, p. 73.

[13] ———. Company News and Mineral Notes. No. 219, Dec. 1985, p. 93.

[14] ———. Company News and Mineral Notes. Diamond and CBN Provide Complete Honing System. No. 209, Feb. 1985, p. 68.

**Table 13.—Crude artificial abrasives manufacturers in 1985**

| Company | Location | Product |
|---|---|---|
| The Exolon-ESK Co | Hennepin, IL | Silicon carbide. |
| Do | Thorold, Ontario, Canada | Fused aluminum oxide (regular) and silicon carbide. |
| General Abrasives, a division of Dresser Industries Inc. | Niagara Falls, NY | Fused aluminum oxide (regular and high-purity). |
| Do | Niagara Falls, Ontario, Canada | Fused aluminum oxide (regular) and silicon carbide. |
| Norton Co | Huntsville, AL | Fused aluminum oxide (high-purity) and aluminum-zirconium oxide. |
| Do | Worcester, MA | General abrasive processing. |
| Do | Cap-de-la-Madeleine, Quebec, Canada | Silicon carbide. |
| Do | Chippewa, Ontario, Canada | Fused aluminum oxide (regular and high-purity) and aluminum-zirconium oxide. |
| Sohio Electro Minerals Co | Niagara Falls, NY | Fused aluminum oxide (high-purity). |
| Do | Niagara Falls, Ontario, Canada | Fused aluminum oxide (regular). |
| Do | Shawinigan, Quebec, Canada | Silicon carbide. |
| Washington Mills Abrasives Co | Niagara Falls, Ontario, Canada | Fused aluminum oxide (regular). |

## Table 14.—Producers[1] of metallic abrasives in 1985

| Company | Location | Product (shot and/or grit) |
|---|---|---|
| Abrasive Materials Inc | Hillsdale, MI | Cut wire. |
| Durasteel Co | Pittsburgh, PA | Steel. |
| Ervin Industries Inc | Adrian, MI | Do. |
| Do | Butler, PA | Do. |
| Globe Steel Abrasives Co | Mansfield, OH | Do. |
| Jumbo Manufacturing Inc | Tippecanoe, IN | Chilled and annealed iron. |
| Metaltec Steel Abrasives Co | Canton, MI | Steel. |
| National Metal Abrasive Co | Wadsworth, OH | Do. |
| The Pangborn Co | Butler, PA | Do. |
| Pellets Inc | Tonawanda, NY | Cut wire. |
| Steel Abrasives Inc | Fairfield, OH | Chilled iron. |
| Wheelabrator-Frye Inc | Bedford, VA | Steel. |

[1] Excludes secondary (salvage) producers.

## Table 15.—Crude manufactured abrasives produced in the United States and Canada, by kind

(Thousand short tons and thousand dollars)

| Kind | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Silicon carbide[1] | 156 | 112 | 109 | 137 | 113 |
| Value | $68,839 | $54,507 | $52,016 | $57,125 | $42,563 |
| Aluminum oxide (abrasive grade)[1] | 203 | 132 | 137 | 177 | 169 |
| Value | $73,712 | $45,975 | $50,565 | $63,818 | $54,061 |
| Aluminum-zirconium oxide | W | 8 | W | W | W |
| Value | W | $4,600 | W | W | W |
| Metallic abrasives[2] | 228 | 166 | 172 | 217 | 197 |
| Value | $82,952 | $62,389 | $64,849 | $82,288 | $75,349 |
| Total | [3]587 | 418 | [3]418 | [3]531 | [3]479 |
| Total value | [3]$225,503 | $167,471 | [3]$167,430 | [3]$203,231 | [3] [4]$171,974 |

W Withheld to avoid disclosing company proprietary data.

[1] Includes material used for refractories and other nonabrasive purposes.

[2] Shipments for U.S. plants only.

[3] Excludes U.S. and Canadian production and value of aluminum-zirconium oxide.

[4] Data do not add to total shown because of independent rounding.

## Table 16.—End uses of crude silicon carbide and aluminum oxide (abrasive grade) in the United States and Canada, as reported by producers

| Use | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Yearend stocks (short tons) | Quantity (short tons) | Value (thousands) | Yearend stocks (short tons) |
| SILICON CARBIDE | | | | | | |
| Abrasives | 50,946 | $22,217 | 6,704 | 46,664 | $18,451 | 6,245 |
| Metallurgical | 71,140 | 28,718 | 6,140 | 53,433 | 19,018 | 5,448 |
| Refractories and other | 14,509 | 6,190 | 3,036 | 12,508 | 5,094 | 1,703 |
| Total | 136,595 | 57,125 | 15,880 | 112,605 | 42,563 | 13,396 |
| ALUMINUM OXIDE | | | | | | |
| Regular: Abrasives plus refractories[1] | 156,814 | 53,740 | 9,175 | 152,401 | 46,705 | 16,993 |
| High purity | 19,856 | 10,078 | 1,950 | 16,422 | 7,356 | 1,769 |
| Total | 176,670 | 63,818 | 11,125 | 168,823 | 54,061 | 18,762 |

[1] Abrasives combined with refractories to avoid disclosing company proprietary data.

## Table 17.—Production, shipments, and annual capacities of metallic abrasives in the United States, by product[1]

| Product | Production | | Shipments | | Annual capacity[2] (short tons) |
|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | |
| 1984: | | | | | |
| Chilled iron shot and grit | W | W | W | W | W |
| Annealed iron shot and grit | W | W | W | W | W |
| Steel shot and grit | 196,921 | $69,653 | 197,946 | $74,368 | 274,500 |
| Other[3] | 20,427 | 8,015 | 20,053 | 7,920 | 41,500 |
| Total | 217,348 | 77,668 | 217,999 | 82,288 | XX |
| 1985: | | | | | |
| Chilled iron shot and grit | W | W | W | W | W |
| Annealed iron shot and grit | W | W | W | W | W |
| Steel shot and grit | 182,655 | 54,404 | 187,381 | 70,647 | 237,000 |
| Other[3] | 17,713 | 7,584 | 10,088 | 4,702 | 41,100 |
| Total | 200,368 | 61,988 | 197,469 | 75,349 | XX |

W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable.

[1] Excludes secondary (recycle) producers.

[2] Total quantity of the various types of metallic abrasives that a plant could have produced during the year, working three 8-hour shifts per day, 7 days per week, allowing for usual interruptions, and assuming adequate fuel, labor, and transportation.

[3] Includes cut wire, aluminum, stainless steel shot, and items indicated by symbol W.

# Aluminum[1]

## By Frank X. McCawley[2]

World production decreased in 1985 as many of the world's major producing countries slowed production in response to high inventories and low metal prices. The largest decrease was in the United States, where production decreased 15% from that of 1984. U.S. annual capacity decreased owing to the closure of three facilities. A major innovation to the domestic aluminum industry was the introduction of alumina tolling into metal by independent companies for major foreign and domestic metal corporations. Despite low prices and an oversupply of metal, new smelters came onstream and production increased in Australia, Brazil, and Canada. Foreign sources of aluminum continued to supply a large share of the U.S. market. Although U.S. exports of aluminum increased substantially, the United States remained a net importer of aluminum.

**Domestic Data Coverage.**—Domestic production data for aluminum are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Aluminum" survey. Of the 11 companies to which monthly survey requests were sent, all responded, representing 100% of the total primary aluminum production shown in tables 1, 6, and 14.

**Table 1.—Salient aluminum statistics**

(Thousand metric tons and thousand dollars unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Primary production | 4,489 | 3,274 | 3,353 | 4,099 | 3,500 |
| Value | $7,520,841 | $5,485,121 | $5,754,298 | $7,319,844 | $6,249,614 |
| Price: Producer list, ingot, average cents per pound | 76.0 | 76.0 | 77.8 | 81.0 | 81.0 |
| Secondary recovery | 1,394 | 1,466 | 1,564 | [1]1,760 | [1]1,762 |
| Exports (crude and semicrude) | 787 | 748 | 776 | 734 | 908 |
| Imports for consumption (crude and semicrude) | 848 | 878 | 1,091 | 1,477 | 1,420 |
| Aluminum industry shipments[2] | 5,644 | 5,090 | [r]5,857 | [r]6,509 | 6,385 |
| Consumption, apparent | 4,614 | 4,370 | 5,035 | 5,279 | 5,174 |
| World: Production | [r]15,079 | [r]13,408 | 13,910 | [p]15,664 | [e]15,289 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Beginning with 1984, metallic recovery from purchased, tolled, or imported new and old aluminum scrap expanded for full industry coverage. Prior to 1984, aluminum recovered from all types of purchased scrap not expanded for full industry coverage.

[2] To domestic industry.

**Legislation and Government Programs.**—The Environmental Protection Agency (EPA) and the Aluminum Association tentatively agreed to new guidelines to regulate the effluents from aluminum plants discharged into water. The original regulations promulgated by EPA in March 1984, under the Clean Water Act, placed strict limits on the discharge of effluents from nonferrous metals plants including primary aluminum smelters, secondary aluminum smelters, and aluminum fabricating plants. The revised guidelines would increase the limits for fluoride and other pollutants from primary plants and for metals, including aluminum, chromium, and zinc, from casting, cooling, and demagging operations from secondary plants. The Aluminum Association in a consolidated lawsuit with other metal companies and metal associations had filed petitions to review the original regulations. In agreeing to the new EPA guidelines, the aluminum companies and the Aluminum Association agreed to dismiss their lawsuit. EPA was to issue new regulations, which affected only the aluminum industry.

Under a proposal for the fiscal year 1987 budget, the Office of Management and Budget proposed the sale of the Bonneville Power Administration (BPA) to private interests. The plan was part of a larger scheme that proposed selling several Government assets to private interests.

The General Accounting Office (GAO) study (GAO/RCED-86-23) on the use of recycled U.S. Department of Defense aluminum to meet the National Defense Stockpile (NDS) goal found that with reprocessing and changes in the stockpile procedures, Department of Defense scrap aluminum could make about a 1% increase per year in meeting the aluminum stockpile goal. However, cost of recycling would be about the same as purchasing like amounts of aluminum on the open market.

On July 8, the President approved the National Security Council (NSC) recommendations for modernizng the strategic and critical materials stockpile. Under the NSC proposal, the NDS would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict that would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. The status of aluminum was deferred until further detailed studies could be made. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984. The current aluminum metal goal is 700,000 short tons but there is only 2,080 tons in the stockpile.

## DOMESTIC PRODUCTION

**Primary.**—Domestic primary production was about 3.5 million metric tons in 1985. As 1985 began, soft metal ingot prices and high world inventories continued to hurt the domestic industry. U.S. producers that began reducing production in mid-1984 to offset declining prices and high inventories continued to shut down production capacity throughout the year. In late 1985, U.S. annual smelter capacity was reduced to 4.7 million tons because of the permanent closures of Reynolds Metals Co.'s 61,700-ton-per-year smelter at Arkadelphia, AR, the 113,400-ton-per-year smelter at Jones Mills, AR, and the permanent closure of Aluminum Co. of America's (Alcoa) 14,500-ton-per-year experimental chloride plant at Palestine, TX. The Arkadelphia and Jones Mills plants both stopped production of metal in October 1985, and the Palestine plant stopped operation in 1983. By yearend 1985, the operating rate of U.S. primary smelters was about 66.4% with 1.74 million tons of the 4.7 million tons of annual capacity shut down compared with 78.2% of the 4.9 million tons operational at yearend 1984. The status of the primary industry at yearend 1985 was 6 smelters permanently closed, 5 smelters temporarily closed, 18 operating at reduced capacity, and 4 operating at full capacity.

Throughout the year, production capacity was shut down as follows: Alcoa shut down a total of about 431,500 tons of annual capacity at Alcoa, TN, Evansville, IN, Massena, NY, Rockdale, TX, Vancouver, WA, and Wenatchee, WA; Kaiser Aluminum & Chemical Corp. shut down 55,300 tons of capacity at Tacoma, WA, and Ravenswood, WV; Reynolds shut down a total of 245,000 tons at Listerhill, AL, Arkadelphia and Jones Mills, AR, Troutdale, OR, and Longview, WA; Alcan Aluminum Corp. shut down 54,400 tons per year at Sebree, KY; and Alumax Inc. shut down a total of 54,400 tons at Mount Holly, SC, and Frederick, MD. Additional closures during the year were 65,300 tons of annual capacity at Commonwealth Aluminum Corp.'s Goldendale, WA, and 100,200 tons per year of capacity at Noranda Aluminum Inc.'s New Madrid, MO, smelters.

The U.S. aluminum producers made several important adjustments that could change the future domestic aluminum industry. In general, companies moved into new ventures such as fiber optics, ceramics, plastics and vinyls, electronics, and other nonaluminum industries. In addition, the companies were relying less on the production of primary ingot, and instead were concentrating on plans for increasing operations in the fabrication end of the industry. In December, Alcoa announced plans to close down 350,000 tons per year of unspecified primary capacity. Reportedly, future supplies of metal could come from outside sources.

Consolidated Aluminum Corp., St. Louis, MO, a subsidiary of Swiss Aluminium Ltd. (Alusuisse), Zurich, Switzerland, reorganized its U.S. operations into two groups, a basic aluminum business and a value-added diversified organization. The basic group was made responsible for production and sale of ingot and mill products from its two-thirds interest in the Ormet Corp. plants in Hannibal, OH, and its wholly owned plant at New Johnsonville, TN. The diversified group included the Madison, IL, aluminum and magnesium extrusion and rolling mill; a lamination plant at Iuka, MS; a metal filtration-metal treatment plant at Hendersonville, SC; and the Benton, KY, composite plant. The reorganization of Consolidated Aluminum from primary production to value-added fabrication apparently followed the lead of its parent Swiss company, Alusuisse.

In March, BPA provided the Direct Service Industries (DSI), which included the aluminum producers of the Pacific Northwest, a 4-month incentive rate of 19.8 mills per kilowatt hour (mills/kW•h) providing the companies purchased a total of 2,282 megawatts (MW) of power from March 1 to July 1. This rate replaced the incentive rate of 22.7 mills/kW•h that ended February 28. In September, BPA again provided an incentive rate to DSI customers, mainly, to maintain the continued operation of the aluminum smelters, which consumed about 30% of BPA's power output, and to protect BPA revenues. The 10-month incentive rate, effective September 1, reduced the power rate to an average of 18.8 mills/kW•h dependent on a guaranteed usage of 2,050 MW. The incentive rate was to run from September 1, 1985, to June 30, 1986, and reduced the standard rate of 23.5 mills/kW•h, about 6 mills from September through March, 3 mills in April, and 1 mill in May and June.

In a long-range plan to provide stable power to the aluminum and other industries of the Pacific Northwest at competitive costs, BPA conducted a DSI Option Study in early 1985. The final report was released in June 1985, and based on the study, BPA explored three courses of action. BPA considered (1) a variable rate structure for the industry that would respond to the fluctuations in the market price for aluminum, (2) establishment of a joint partnership program for aluminum plant conservation-modernization to finance the modernization of aluminum smelters and stabilize BPA revenues, and (3) the establishment of a functional long-term link between the BPA rate for Industrial Firm (IP) power sold to industries and the weighted average BPA rate charged for Priority Firm (PF) power sold to preference customers, mainly regional utility organizations. One other option considered was no action. Final decisions on these proposals would be made by BPA after public comments and the Environmental Impact Statement have been completed.[3] In December, BPA proposed an initial variable sliding rate scale of 13.8 to 29.1 mills/kW•h tied to the world market price of aluminum.

Reynolds announced that it would terminate its 8-year power contract with the Arkansas Power and Light Co. (AP&L) on January 1, 1987, rather than pay higher electric costs imposed by the utility company following the July 1985 startup of a nuclear powerplant at Grand Gulf, MS. AP&L was required to absorb about 21% of the nuclear plant cost as a participant in a four-utility consortium, and Reynolds reportedly was required to share costs of any new AP&L generating capacity. Estimated costs to Reynolds of the increase in power was about $20 million per year. The increased power costs were a factor in the shutdown of the Arkadelphia and Jones Mills, AR, smelters in October and the permanent closing of the plants in November.

In November, National-Southwire Aluminum Co. announced that it would petition the Kentucky Public Service Commission to reduce the cost from 28 to 22 mills/kW•h for power it purchases from the Big Rivers Electric Corp., Henderson, KY, for the 172,000-ton-per-year Hawesville, KY, smelter. National-Southwire reportedly alleged that Big Rivers is paying too much for coal. National-Southwire also indicated that it could be subsidizing the Alcan 163,000-ton-per-year Sebree, KY, smelter power payments as a result of an Alcan-Big Rivers agreement for linking power costs to the London Metal Exchange (LME) price for metal. Other factors affecting Big Rivers was the notification by the Rural Electrification Administration (REA) that the utility was to pay back $1.1 billion in loans obtained from REA since 1961. Big Rivers was further saddled with a $756 million debt for a coal-fired powerplant it does not need. About 75% of the power sold by Big Rivers was purchased by the National-Southwire Hawesville and Alcan Sebree smelters, and discussions among all parties concerned were expected to be long and detailed. The ultimate operations of the two smelters could rest on the final decisions on power rates.

Alumax, in November, requested a rehearing on the September 1 ruling by the Maryland Public Service Commission that allowed Potomac Edison Co. to increase power costs for the 160,000-ton-per-year Eastalco smelter at Frederick, MD. A rate increase from 24 to 24.8 mills/kW•h was granted Potomac Edison and an additional increase to 26.4 mills/kW•h to cover charges associated with the startup of a new power station was under consideration. In December, Alumax signed an agreement with the State-owned South Carolina Santee Cooper Power Co. electric utility to reduce the power rate for the 181,000-ton-per-year Mount Holly, SC, smelter from 32.9 mills/kW•h to a low of 26 mills/kW•h in the years 1986 to 1991 based on the market price of aluminum ingot. The agreement followed a decision by Santee Cooper that granted Mount Holly a decrease to 30 mills/kW•h for the fiscal year beginning July 1. According to the agreement, Alumax must operate the smelter at 290 MW, to receive a 26-mill/kW•h rate, otherwise the rate would increase proportionally with a decrease in demand to 243 MW. Furthermore, the discount would only apply when the average monthly market price is 62 cents per pound or below. Between 62 cents and 72 cents, there would be no discount, and above 72 cents, Alumax would repay the cost discount. During the period 1991 through 1993, Alumax would be obligated to repay the discounts.

The expansion of the Reynolds' extrusion plant at Torrance, CA, including the installation of a new 3,150-ton extrusion press was completed in October. The expansion and modernization project increased the annual capacity of the plant from 12,000 to 21,500 tons. The new press is computer-controlled and is capable of producing seamless tubing. After a 2-1/2-month strike, production resumed at Reynolds' aluminum extrusion plant in Grand Rapids, MI, following ratification of a new contract by the 350 hourly workers.

National Aluminum Corp., a subsidiary of National Intergroup Inc., announced plans to construct a new extrusion plant in Anniston, AL. The plant would contain several extrusion presses and a paint line and was expected to be operational by fall 1986. National Aluminum has other extrusion plants at Murraysville, PA, and Indianapolis, IN.

Mitsubishi Aluminium Co. of Japan and Thermal Components Inc., Montgomery, AL, announced the formation of an equity joint venture, Thermalex Inc., to construct a new 36,000-ton-per-year aluminum extrusion plant at Thermal Components facility in Montgomery. The plant, including a 1,650-ton press, heating furnace, and related equipment was expected to be transferred from Mitsubishi Corp.'s Fuji, Shizuoka Prefecture, plant for installation at the Montgomery facility. Production was expected by the summer of 1986.

Pechiney Corp., the U.S. subsidiary of Pechiney, France, was to acquire International Container Corp.'s aluminum aerosol can mill at Waterbury, CT. A new company, Pechiney-Cebal Corp., would operate the mill as a subsidiary of Pechiney Corp. The mill had an annual capacity of 30 million aerosol cans but was expected to be expanded to a capacity of 60 million cans.

Alcan Cable, a division of Alcan Aluminum, announced the $600,000 expansion and modernization of its aluminum cable facility at Williamsport, PA. The expansion included a new metal processing furnace and related equipment. Nichols-Homeshield, Aurora, IL, announced the expansion of its aluminum wire operations in Florence, AL, by consolidating production into one large facility. A small wire production line, which operated at a plant in Davenport, IA, was being moved to the Alabama plant.

Norandal USA Inc., a subsidiary of Noranda Aluminum, completed its acquisition of the Revere Copper and Brass Inc.'s aluminum rolling mill at Scottsboro, AL, as part of its program to increase its value-added products involvement. The sale of the mill by Revere required the approval of the bankruptcy court of New York. Revere had been operating the mill under chapter 11 of the Federal Bankruptcy Code, and sale of the mill as part of Revere's reorganization plan required approval of the court overseeing the reorganization. The mill would continue to produce sheet and plate with primary aluminum supplied by Noranda's 204,000-ton-per-year smelter at New Madrid, MO. The Revere Scottsboro primary smelter was not included in the transaction.

Commonwealth Aluminum was incorporated as the U.S. subsidiary of Comalco Pty. Ltd., Australia, which in late 1984 purchased most of the aluminum operations of Martin Marietta Corp. They included a 168,000-ton-per-year Goldendale, WA, primary smelter; a 109,000-ton-per-year rolling mill and 204,000-ton-per-year recycling plant at Lewisport, KY; an alumina unloading port at Portland, OR; and other assets.

Newly formed Northwest Aluminum Co., a group headed by a former executive director of BPA for DSI companies, was granted the exclusive rights to negotiate the purchase of Martin Marietta's 82,000-ton-per-year The Dalles, OR, smelter. The smelter was shut down by Martin Marietta in December 1984 when no buyer for the operation was found.

In September, Atlantic Richfield Co. (ARCO) sold the ARCO Aluminum Co.'s 163,000-ton-per-year Columbia Falls, MT, aluminum smelter to a group of investors headed by a former ARCO executive. The group, Montana Aluminum Investors Corp., began operation of the smelter through the Columbia Falls Aluminum Co. The plant was purchased with financial underwriting from the Montana Board of Investments under a provision that overhead, salaries, hourly labor costs, and BPA energy costs were reduced. The new management announced the smelter would be converted into an international alumina tolling facility following the complete processing of the existing ARCO inventory of alumina in April 1986.

In September, a group of investors headed by Joseph A. Frates, who successfully acquired Kaiser Steel Corp. in 1984, began an attempt to take over Kaiser, Oakland, CA, by filing an intent with the Securities Exchange Commission. The group reportedly announced that it would dispose of all Kaiser assets except the aluminum and industrial chemicals. Kaiser rejected the Frates group's initial offer; however, in December, the group had acquired 14.4% of Kaiser and was offering shareholders $20 per share consisting of $7 cash and $13 in securities. The group also announced that it would consider replacing the company's directors with their own selection. By yearend, it was apparent a major proxy fight was forming between Kaiser and the Frates group.

Alcan and Reynolds announced that Reynolds would purchase Alcan's Metals Goods Div. The division, housed in St. Louis, MO, operated 27 service centers, which distributed aluminum, nickel, stainless steel, and steel. Reynolds indicated the centers would be incorporated into its Reynolds Aluminum Supply Co. Div., which operated distribution service centers in the Southeast, lower Midwest, and West.

In March, Kaiser renegotiated a new 3-year labor contract with the United Steelworkers of America (USWA) for a reduction in wages and benefits. Kaiser's new labor contract replaced the master contract that would have expired on May 31, 1986. The contract called for a total wage and benefit cost reduction of an average of $4.50 per hour, the loss of some paid holidays, and modifications to vacation time and health insurance benefits. In return, the workers would receive a series of preferred stocks that would accumulate in a trust. About 6,500 workers were covered by the contract, which was expected to save the company about $50 million per year.

### Table 2.—Primary aluminum production capacity in the United States, by company

| Company | Yearend capacity (thousand metric tons) 1975 | Yearend capacity (thousand metric tons) 1985 | 1985 ownership (percent) |
|---|---|---|---|
| Alcan Aluminum Corp.: | | | |
| Sebree, KY[1] | 109 | 163 | Alcan Aluminium Ltd., 100%. |
| Alumax Inc.: | | | |
| Ferndale, WA (Intalco)[2] | 236 | 254 | AMAX Inc., 50%; Mitsui & Co., 45%; Nippon Steel Corp., 5%. |
| Frederick, MD (Eastalco)[2] | 160 | 160 | Do. |
| Mount Holly, SC | 179 | 181 | Do. |
| Total | 575 | 595 | |
| Aluminum Co. of America: | | | |
| Alcoa, TN | 245 | 200 | Aluminum Co. of America, 100%. |
| Badin, NC | 109 | 115 | Do. |
| Evansville, IN (Warrick) | 254 | 270 | Do. |
| Massena, NY | 122 | 205 | Do. |
| Palestine, TX[3] | -- | -- | Do. |
| Point Comfort, TX | 163 | -- | Do. |
| Rockdale, TX | 258 | 310 | Do. |
| Vancouver, WA | 104 | 110 | Do. |
| Wenatchee, WA | 163 | 205 | Do. |
| Total | 1,418 | 1,415 | |
| Columbia Falls Aluminum Co.: | | | |
| Columbia Falls, MT[4] | 163 | 163 | Montana Aluminum Investors Corp., 100%. |
| Commonwealth Aluminum Corp.: | | | |
| Goldendale, WA[5] | 109 | 163 | Comalco Pty. Ltd., 100%. |
| Consolidated Aluminum Corp.: | | | |
| Lake Charles, LA[6] | 33 | -- | Swiss Aluminium Ltd., 100%. |
| New Johnsonville, TN | 128 | 131 | Do. |
| Total | 161 | 131 | |
| Kaiser Aluminum & Chemical Corp.: | | | |
| Chalmett, LA | 236 | 236 | Kaiser Aluminum & Chemical Corp., 100%. |
| Mead, WA (Spokane) | 200 | 200 | Do. |
| Ravenswood, WV | 148 | 148 | Do. |
| Tacoma, WA | 73 | 73 | Do. |
| Total | 657 | 657 | |
| Martin Marietta Aluminum Inc.: | | | |
| The Dalles, OR | 82 | 82 | Martin Marietta Corp., 87.2%; private interests, 12.8%. |
| National-Southwire Aluminum Co.: | | | |
| Hawesville, KY | 163 | 172 | National Steel Corp., 50%; Southwire Co., 50%. |
| Noranda Aluminum Inc.: | | | |
| New Madrid, MO | 64 | 204 | Noranda Mines Ltd., 100%. |
| Ormet Corp.: | | | |
| Hannibal, OH | 236 | 245 | Consolidated Aluminum Corp., 66%; Revere Copper and Brass Inc., 34%. |
| Revere Copper and Brass Inc.: | | | |
| Scottsboro, AL | 103 | 105 | Revere Copper and Brass Inc., 100%. |
| Reynolds Metals Co.: | | | |
| Arkadelphia, AR | 62 | -- | Reynolds Metals Co., 100%. |
| Corpus Christi, TX | 103 | -- | Do. |
| Jones Mills, AR | 113 | -- | Do. |
| Listerhill, AL | 183 | 183 | Do. |
| Longview, WA | 190 | 191 | Do. |
| Massena, NY | 114 | 114 | Do. |
| Troutdale, OR | 118 | 118 | Do. |
| Total | 883 | 606 | |
| Grand total | 4,723 | 4,706 | |

[1] Purchased from ARCO Metals Co. in 1985, which purchased from Anaconda Aluminum Co. in 1982.
[2] Alumax Inc. purchased equity share from Howmet Inc. in 1983.
[3] Experimental 16,000-ton-per-year chloride reduction plant opened in 1976, closed Dec. 1985.
[4] Purchased from ARCO Metals in 1985, which purchased from Anaconda Aluminum in 1982.
[5] Purchased from Martin Marietta Aluminum Inc. in 1985.
[6] Sold to Reynolds Metals Co. in 1983.

**Secondary.**—Consumption of purchased new and old aluminum scrap was about 1.9 million tons, the same as that of 1984. Recycled used beverage cans (UBC) continued to be a major source of old scrap. According to the Aluminum Association, 33.1 billion aluminum cans were recycled in 1985 representing about 51% of aluminum cans shipped.[4] The recycling effort of UBC represented an estimated energy savings of about 9.5 billion kilowatts of electricity.

In September, Alcoa opened a new aluminum UBC plant in Edison, NJ, which processed cans from 11 Eastern States. The plant was expected to sort and bale about 36 million cans per year. The recycled cans were sent to Alcoa's Tennessee facilities for remelting and fabrication into can sheet stock.

Allied Metals Co., Chicago, IL, delivered its first 37,000-pound shipment of molten metal from its Division Street plant to a diecasting facility in August. The plant, acquired from Harco Aluminum Co. during a bankruptcy sale in 1984, was modernized for molten metal operation with a new 190,000-pound-capacity reverberatory furnace, and three 18,000-pound-capacity holding vessels to accommodate the molten metal, and a 60-short-ton-capacity crane to load the vessels on custom-made trailers. The new equipment reportedly reduced the cost of heating gas per pound of metal produced.

Alumax, San Mateo, CA, closed its Rockwell, TX, secondary smelter at yearend 1984 for an indefinite period of time reportedly because of an oversupply of primary aluminum ingot in the company's system. The Rockwell smelter, acquired as part of Howmet Aluminum Corp., a subsidiary of Pechiney, in 1983, was producing about 75 million pounds of rolling ingot and billet annually for Alumax's Lancaster, PA, rolling mill and Magnolia, AR, extrusion plants, respectively.

Charles Batchelder Co. Inc., a Connecticut secondary aluminum smelter, asked creditors to delay their request for payments in order to avoid filing a chapter 11 petition for bankruptcy protection. The company's financial problems were the result of an explosion in April 1984 that caused a loss of production for a long period and a low volume of sales after production resumed. The company was seeking a loan of about $3 million to help reestablish its financial condition.

Huron Valley Steel Corp., Beltsville, MI, ceased production of secondary aluminum ingot at its Trenton, MI, facility. The plant produced about 36 million pounds of secondary aluminum from scrap. The company was expected to remain in the secondary aluminum business by providing aluminum scrap to the U.S. Reduction Co. for processing at the Toledo, OH, facility.

A new secondary aluminum smelter was scheduled to open in Hammond, IN, by Standard Alloys Corp. The corporation, headed by a former officer of Wabash Alloys Inc., expected secondary aluminum sales to exceed $35 million per year.

## CONSUMPTION

Apparent consumption of aluminum metal decreased by less than 2% in 1985 compared with that of 1984. Although the largest consumer of aluminum in 1985 was the containers and packaging industry, accounting for 27% of the total shipments, the increase in consumption of metal by this sector was less than 2%. The low growth rate was, in part, the result of improved technology to produce a thinner walled and lighter weight beverage can.

## Table 3.—U.S. consumption of and recovery from purchased new and old aluminum scrap,[1] by class

(Metric tons)

| Class | Consumption | Calculated recovery | |
|---|---|---|---|
| | | Aluminum | Metallic |
| **1984** | | | |
| Secondary smelters | 792,907 | 633,287 | 684,500 |
| Primary producers | 782,105 | 654,642 | 701,926 |
| Fabricators | 192,288 | 164,342 | 175,949 |
| Foundries | 94,141 | 78,482 | 84,417 |
| Chemical producers | 37,217 | 16,707 | 17,277 |
| Total | 1,898,658 | 1,547,460 | 1,664,069 |
| Estimated full industry coverage | 2,010,000 | 1,637,000 | 1,760,000 |
| **1985** | | | |
| Secondary smelters | 853,722 | 702,136 | 757,674 |
| Primary producers | 725,890 | 611,371 | 655,250 |
| Fabricators | 178,494 | 154,310 | 165,074 |
| Foundries | 93,680 | 78,209 | 84,163 |
| Chemical producers | 26,758 | 12,246 | 13,113 |
| Total | 1,878,544 | 1,558,272 | 1,675,274 |
| Estimated full industry coverage | 1,978,000 | 1,638,000 | 1,762,000 |

[1] Excludes recovery from other than aluminum-base scrap.

## Table 4.—U.S. stocks, receipts, and consumption of purchased new and old aluminum scrap[1] and sweated pig in 1985

(Metric tons)

| Class of consumer and type of scrap | Stocks, Jan. 1 | Net receipts[2] | Consumption | Stocks, Dec. 31 |
|---|---|---|---|---|
| Secondary smelters: | | | | |
| New scrap: | | | | |
| Solids | [r]11,979 | 213,196 | 208,819 | 16,356 |
| Borings and turnings | [r]7,211 | 124,742 | 125,130 | 6,823 |
| Dross and skimmings | [r]7,741 | 60,119 | 63,537 | 4,323 |
| Other[3] | [r]2,909 | 32,695 | 34,682 | 922 |
| Total | [r]29,840 | 430,752 | 432,168 | 28,424 |
| Old scrap: | | | | |
| Castings, sheet, clippings | [r]7,193 | 148,400 | 148,593 | 7,000 |
| Aluminum-copper radiators | [r]1,265 | 15,381 | 15,429 | 1,217 |
| Aluminum cans | [r]6,816 | [4]173,495 | [4]178,083 | 2,228 |
| Other[5] | [r]37 | 2,231 | 2,234 | 34 |
| Total | [r]15,311 | 339,507 | 344,339 | 10,479 |
| Sweated pig | [r]9,324 | 75,249 | 77,215 | 7,358 |
| Total secondary smelters | [r]54,475 | 845,508 | 853,722 | 46,261 |
| Primary producers, foundries, fabricators, chemical plants: | | | | |
| New scrap: | | | | |
| Solids | [r]17,373 | 443,826 | 438,738 | 22,461 |
| Borings and turnings | 192 | 24,473 | 24,559 | 106 |
| Dross and skimmings | [r]690 | 22,462 | 22,766 | 386 |
| Other[3] | [r]7,209 | 46,751 | 48,487 | 5,473 |
| Total | [r]25,464 | 537,512 | 534,550 | 28,426 |
| Old scrap: | | | | |
| Castings, sheet, clippings | [r]959 | 52,117 | 52,162 | 914 |
| Aluminum-copper radiators | 11 | 1,532 | 1,515 | 28 |
| Aluminum cans | 25,956 | 377,232 | 392,407 | 10,781 |
| Other[5] | 2,742 | 19,467 | 20,467 | 1,742 |
| Total | [r]29,668 | 450,348 | 466,551 | 13,465 |
| Sweated pig | [r]654 | 23,363 | 23,721 | 296 |
| Total primary producers, etc | [r]55,786 | 1,011,223 | 1,024,822 | 42,187 |

See footnotes at end of table.

## Table 4.—U.S. stocks, receipts, and consumption of purchased new and old aluminum scrap[1] and sweated pig in 1985 —Continued

(Metric tons)

| Class of consumer and type of scrap | Stocks, Jan. 1 | Net receipts[2] | Consumption | Stocks, Dec. 31 |
|---|---|---|---|---|
| All scrap consumed: | | | | |
| New scrap: | | | | |
| Solids | [r]29,352 | 657,022 | 647,557 | 38,817 |
| Borings and turnings | [r]7,403 | 149,215 | 149,689 | 6,929 |
| Dross and skimmings | [r]8,431 | 82,581 | 86,303 | 4,709 |
| Other | [r]10,118 | 79,446 | 83,169 | 6,395 |
| Total new scrap | [r]55,804 | 968,264 | 966,718 | 56,850 |
| Old scrap: | | | | |
| Castings, sheet, clippings | [r]8,152 | 200,517 | 200,755 | 7,914 |
| Aluminum-copper radiators | [r]1,276 | 16,913 | 16,944 | 1,245 |
| Aluminum cans | [r]32,772 | 550,727 | 570,490 | 13,009 |
| Other | 2,779 | 21,698 | 22,701 | 1,776 |
| Total old scrap | [r]44,979 | 789,855 | 810,890 | 23,944 |
| Sweated pig | [r]9,978 | 98,612 | 100,936 | 7,654 |
| Total of all scrap consumed | [r]110,261 | 1,856,731 | 1,878,544 | 88,448 |

[r] Revised.

[1] Includes imported scrap. According to reporting companies, 6.63% of total receipts of aluminum-base scrap, or 123,060 metric tons, was received on toll arrangements.

[2] Includes inventory adjustment.

[3] Includes data on foil, can stock clippings, and other miscellaneous.

[4] Used beverage cans toll treated for primary producers are included in secondary smelter tabulation.

[5] Includes municipal wastes (includes litter) and fragmentized scrap (auto shredder).

## Table 5.—Production and shipments of secondary aluminum alloys by independent smelters in the United States

(Metric tons)

| | 1984 | | 1985 | |
|---|---|---|---|---|
| | Production | Net shipments[1] | Production | Net shipments[1] |
| Die-cast alloys: | | | | |
| 13% Si, 360, etc. (0.6% Cu, maximum) | 110,904 | 111,549 | 111,361 | 111,042 |
| 380 and variations | 286,458 | 285,374 | 279,892 | 278,868 |
| Sand and permanent mold: | | | | |
| 95/5 Al-Si, 356, etc. (0.6% Cu, maximum) | 30,188 | 30,487 | 26,475 | 27,474 |
| No. 12 and variations | W | W | W | W |
| No. 319 and variations | 53,647 | 53,184 | 43,940 | 44,720 |
| F-132 alloy and variations | 13,535 | 13,296 | 12,116 | 12,419 |
| Al-Mg alloys | 548 | 632 | 292 | 410 |
| Al-Zn alloys | 4,095 | 4,309 | 5,154 | 4,955 |
| Al-Si alloys (0.6% to 2.0% Cu) | 4,293 | 4,337 | 5,593 | 5,490 |
| Al-Cu alloys (1.5% Si, maximum) | 2,573 | 2,512 | 1,807 | 2,113 |
| Al-Si-Cu-Ni alloys | 2,406 | 2,250 | 1,012 | 1,012 |
| Other | 481 | 495 | 664 | 653 |
| Wrought alloys: Extrusion billets | 107,292 | 105,684 | 97,168 | 96,929 |
| Miscellaneous: | | | | |
| Steel deoxidation | 23,778 | 23,084 | 27,735 | 28,010 |
| Pure (97.0% Al) | 168 | 169 | 168 | 168 |
| Aluminum-base hardeners | 1,557 | 1,566 | 1,236 | 1,275 |
| Other[2] | 6,799 | 6,788 | 14,504 | 14,305 |
| Total | 648,722 | 645,716 | 629,117 | 629,843 |
| Less consumption of materials other than scrap: | | | | |
| Primary aluminum | 41,443 | -- | 45,034 | -- |
| Primary silicon | 35,093 | -- | 25,028 | -- |
| Other | 2,316 | -- | 2,227 | -- |
| Net metallic recovery from aluminum scrap and sweated pig consumed in production of secondary aluminum ingot[3] | 569,870 | XX | 556,828 | XX |

W Withheld to avoid disclosing company proprietary data; included with "Sand and permanent mold: Other."

XX Not applicable.

[1] Includes inventory adjustment.

[2] Includes other die-cast alloys and other miscellaneous.

[3] No allowance made for melt-loss of primary aluminum and alloying ingredients.

## Table 6.—U.S. apparent aluminum supply and consumption

(Thousand metric tons)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Primary production | 4,489 | 3,274 | 3,353 | 4,099 | 3,500 |
| Change in stocks:[1] Aluminum industry | -694 | +184 | +547 | -388 | +312 |
| Imports | 848 | 878 | 1,091 | 1,477 | 1,420 |
| Secondary recovery:[2] | | | | | |
| New scrap | 1,031 | 884 | 953 | 935 | 912 |
| Old scrap | 758 | 782 | 820 | 825 | 850 |
| Total supply | 6,432 | 6,002 | 6,764 | 6,948 | 6,994 |
| Less total exports | 787 | 748 | 776 | 734 | 908 |
| Apparent aluminum supply available for domestic manufacturing | 5,645 | 5,254 | 5,988 | 6,214 | 6,086 |
| Apparent consumption[3] | 4,614 | 4,370 | 5,035 | 5,279 | 5,174 |

[1] Positive figure indicates a decrease in stocks; negative figure indicates an increase in stocks.

[2] Metallic recovery from purchased, tolled, or imported new and old aluminum scrap expanded for full industry coverage.

[3] Apparent aluminum supply available for domestic manufacturing less recovery from purchased new scrap (a measure of consumption in manufactured end products).

## Table 7.—Distribution of end-use shipments of aluminum products in the United States, by industry

| Industry | 1983 | | 1984 | | 1985$^{p}$ | |
|---|---|---|---|---|---|---|
| | Quantity (thousand metric tons) | Percent of grand total | Quantity (thousand metric tons) | Percent of grand total | Quantity (thousand metric tons) | Percent of grand total |
| Containers and packaging | 1,777 | ${}^{r}$27.7 | 1,829 | 26.1 | 1,863 | 26.9 |
| Building and construction | 1,302 | 20.3 | 1,295 | 18.5 | 1,381 | 19.9 |
| Transportation | ${}^{r}$1,062 | ${}^{r}$16.5 | 1,370 | 19.5 | 1,364 | 19.7 |
| Electrical | 589 | 9.2 | 677 | 9.7 | 642 | 9.3 |
| Consumer durables | 478 | ${}^{r}$7.4 | 502 | 7.2 | 477 | 6.9 |
| Machinery and equipment | 353 | 5.5 | 375 | 5.4 | 377 | 5.4 |
| Other markets | ${}^{r}$261 | ${}^{r}$4.1 | 274 | 3.9 | 265 | 3.8 |
| Statistical adjustment | ${}^{r}$+35 | ${}^{r}$.5 | +187 | 2.7 | +16 | .2 |
| Total to domestic users | ${}^{r}$5,857 | 91.2 | 6,509 | 93.0 | 6,385 | 92.1 |
| Exports | 563 | 8.8 | 488 | 7.0 | 546 | 7.9 |
| Grand total | ${}^{r}$6,420 | 100.0 | 6,997 | 100.0 | 6,931 | 100.0 |

$^{p}$Preliminary. $^{r}$Revised.

Source: The Aluminum Association Inc.

## Table 8.—U.S. net shipments[1] of aluminum wrought and cast products, by producers

(Metric tons)

| | 1983 | 1984 | 1985$^{p}$ |
|---|---|---|---|
| Wrought products: | | | |
| Sheet, plate, foil | ${}^{r}$3,248,948 | 3,259,163 | 3,288,544 |
| Extruded rod, bar, pipe, tube, shapes; drawn and welded tubing | ${}^{r}$1,037,526 | 1,182,458 | 1,240,482 |
| Rolled and continuous-cast rod and bar; wire | ${}^{r}$423,024 | 451,493 | 378,700 |
| Forgings (including impacts) | 52,711 | 65,398 | 67,180 |
| Powder, flake, paste | ${}^{r}$35,675 | 44,758 | 48,670 |
| Total | ${}^{r}$4,797,884 | 5,003,270 | 5,023,576 |
| Castings: | | | |
| Sand | ${}^{r}$75,503 | 89,651 | 120,736 |
| Permanent mold | ${}^{r}$137,122 | 160,566 | 151,745 |
| Die | ${}^{r}$592,475 | 679,159 | 565,017 |
| Other | ${}^{r}$55,881 | 61,092 | 36,850 |
| Total | ${}^{r}$860,981 | 990,468 | 874,348 |
| Grand total | ${}^{r}$5,658,865 | 5,993,738 | 5,897,924 |

$^{p}$Preliminary. $^{r}$Revised.

[1] Net shipments derived by subtracting the sum of producers' domestic receipts of each mill shape from the domestic industry's gross shipments of that shape.

Source: U.S. Department of Commerce.

### Table 9.—Distribution of wrought products in the United States

(Percent)

| | 1983 | 1984 | 1985[p] |
|---|---|---|---|
| Sheet, plate, foil: | | | |
| Nonheat-treatable | [r]56.9 | 53.8 | 55.4 |
| Heat-treatable | 3.1 | 3.6 | 2.7 |
| Foil | 7.8 | 7.8 | 7.3 |
| Rolled and continuous-cast rod and bar; wire: | | | |
| Rod, bar, wire | 2.3 | 2.3 | 1.5 |
| Cable and insulated wire | 6.5 | 6.7 | 6.1 |
| Extruded products: | | | |
| Rod and bar | [r]1.1 | 1.1 | 1.3 |
| Pipe and tubing | 1.3 | 1.6 | 2.3 |
| Shapes | [r]18.1 | 19.9 | 21.1 |
| Tubing: | | | |
| Drawn | .6 | .5 | NA |
| Welded | .5 | .5 | NA |
| Powder, flake, paste | .7 | .9 | 1.0 |
| Forgings (including impacts) | 1.1 | 1.3 | 1.3 |
| Total | 100.0 | 100.0 | 100.0 |

[p]Preliminary. [r]Revised. NA Not available.

Source: U.S. Department of Commerce.

## STOCKS

Inventories of aluminum ingot, mill products, and scrap at reduction and other processing plants as reported by the Bureau of Industrial Economics, U.S. Department of Commerce, decreased from about 2.65 million tons at yearend 1984 to about 2.35 million tons at yearend 1985.

## PRICES

The producer list price for 99.5%-pure aluminum ingots remained at 81 cents per pound throughout 1985. Several domestic producers continued to maintain the transaction price, a price more comparable with the market or spot price. At yearend 1984, the average weekly market price for aluminum ingot, usually 99.7% pure, as published by Metals Week (McGraw-Hill), was 50.2 cents per pound. By yearend January 1985, the price had risen to about 52 cents. The price remained relatively stable until April when it began to soften, reaching about 46.5 cents by July 1. It remained weak during the summer and early autumn before declining to a 1985 low of 45 cents in mid-November. During the last half of November and during December, the market price increased rapidly, closing out the year at a weekly average of about 53 cents per pound.

Both the LME and New York Commodity Exchange (COMEX) prices for aluminum futures followed the same general trend as the market prices. However, the LME cash price, as published by Metals Week, was usually about 2 to 3 cents lower than the U.S. market price until November, when the difference in prices was about 4 cents per pound. COMEX prices, when compared with market prices, were usually 2 to 4 cents lower per pound for metal with short delivery dates and about 1 to 2 cents higher per pound with longer delivery dates. Producer U.S. transaction prices, as published by Metals Week, were usually plus or minus 0.5 cent per pound of the market price. The following table summarizes aluminum prices at selected dates during the year, in cents per pound:

| | COMEX 1[1] | COMEX 2[1] | COMEX 3[1] | LME (cash) | U.S. market | U.S. transaction |
|---|---|---|---|---|---|---|
| 1984: December 31 | 47.21 | 47.92 | 51.82 | 47.64 | 49.75-50.75 | 49.72 |
| 1985: | | | | | | |
| January 28 | 49.48 | 49.99 | 53.62 | 49.63 | 50.75-52.00 | 51.33 |
| February 25 | 49.25 | 49.84 | 53.54 | 49.74 | 51.25-52.25 | 51.54 |
| March 25 | 49.15 | 49.69 | 53.89 | 49.83 | 51.25-52.50 | 51.82 |
| April 29 | 48.65 | 49.18 | 52.76 | 50.72 | 52.25-53.00 | 52.71 |
| May 27 | 48.11 | 48.58 | 52.07 | 50.11 | 51.75-52.50 | 51.93 |
| June 24 | 44.83 | 45.27 | 48.30 | 46.67 | 47.75-48.75 | 48.27 |
| July 29 | 44.52 | 44.97 | 48.29 | 45.77 | 47.00-48.00 | 47.04 |
| August 26 | 44.97 | 45.46 | 48.67 | 46.26 | 47.75-48.35 | 46.78 |
| September 30 | 43.09 | 43.72 | 47.20 | 44.60 | 46.25-46.75 | 45.69 |
| October 28 | 42.96 | 43.47 | 46.67 | 43.55 | 45.50-46.00 | 45.44 |
| November 25 | 43.63 | 44.17 | 47.18 | 43.39 | 45.25-46.00 | 45.66 |
| December 30 | 51.03 | 51.49 | 54.64 | 48.76 | 52.00-53.50 | 52.21 |

[1] COMEX delivery positions: 1—within 1 month; 2—within 3 months; and 3—within 12 months.

Source: Metals Week.

Secondary aluminum prices, as quoted in the American Metal Market, followed a price trend similar to that of primary aluminum. Secondary aluminum alloy 360 and 413 began the year at about 68 to 70 cents per pound. In July, alloy 360 had declined to 57 to 58 cents and alloy 413 was 58 to 59 cents. Prices of these alloys began to increase about September, and by yearend, alloy 413 was 62 to 63 cents and alloy 360 was 61 to 62 cents per pound. Alloy 380 was about 3 to 4 cents per pound lower than alloys 413 and 360. Buying prices of old sheet and cast aluminum scrap ranged from a high of about 35 cents per pound in February to a low of 28 cents in July and August. UBC scrap, processed and delivered to producers, was bought throughout the year at a range of from 29 to 39 cents per pound.

## FOREIGN TRADE

Exports of all forms of aluminum from the United States increased substantially from the 1984 level. Canada, Japan, and Mexico accounted for most of the increase, reflecting increased shipments of crude metal and scrap to Japan and of crude metal to Canada and Mexico. Exports of plates, sheets, bars, etc., decreased from 1984, reflecting a decrease of shipments to the United Kingdom. Imports of aluminum in all forms decreased slightly from those of 1984, but total imports remained substantially greater than the quantity of aluminum exported. In descending order, the major aluminum shipping countries to the United States were Canada, Japan, Venezuela, Brazil, Belgium-Luxembourg, the United Arab Emirates, and Argentina. Canada provided most of the ingot and scrap metal while Japan, Venezuela, and Belgium-Luxembourg supplied most of the semicrude forms. Bahrain, a large supplier of ingots in 1984, reduced its supply to the United States by about 60%.

U.S. tariff rates in effect during 1985 for aluminum products from countries with most-favored-nation status were as follows:

| Item | TSUS No. | Import duty |
|---|---|---|
| Unwrought metal (in coils) | 618.01 | 2.8% ad valorem. |
| Unwrought (other than Si-Al alloys) | 618.02 | 0.2 cent per pound. |
| Wrought (bars, plates, sheets, strip) | 618.25 | 3% ad valorem. |
| Waste and scrap | 618.10 | 2% ad valorem. |

## Table 10.—U.S. exports of aluminum, by class

| Class | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Crude and semicrude: |  |  |  |  |
| Metals and alloys, crude | 259,598 | $396,798 | 347,292 | $441,598 |
| Scrap | 258,404 | 275,686 | 374,646 | 350,669 |
| Plates, sheets, bars, etc. | 198,399 | 496,841 | 167,874 | 411,337 |
| Castings and forgings | 11,590 | 69,845 | 12,408 | 74,498 |
| Semifabricated forms, n.e.c | 5,822 | 34,259 | 5,656 | 32,984 |
| Total | 733,813 | 1,273,429 | 907,876 | 1,311,086 |
| Manufactures: |  |  |  |  |
| Foil and leaf | 21,369 | 33,320 | 19,497 | 28,800 |
| Powders and flakes | 3,219 | 11,951 | 2,492 | 9,838 |
| Wire and cable | 4,824 | 14,535 | 5,619 | 15,358 |
| Total | 29,412 | 59,806 | 27,608 | 53,996 |
| Grand total | 763,225 | 1,333,235 | 935,484 | 1,365,082 |

Source: Bureau of the Census.

## Table 11.—U.S. exports of aluminum, by country

| Country | Metals and alloys, crude |  | Plates, sheets, bars, etc.[1] |  | Scrap |  | Total |  |
|---|---|---|---|---|---|---|---|---|
|  | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1984: |  |  |  |  |  |  |  |  |
| Argentina | 44 | $197 | 119 | $717 | 18 | $17 | 181 | $931 |
| Australia | 1,517 | 2,494 | 1,537 | 6,642 | 339 | 445 | 3,393 | 9,581 |
| Belgium-Luxembourg | 10 | 25 | 495 | 2,441 | 1,632 | 1,610 | 2,137 | 4,076 |
| Brazil | 278 | 1,404 | 1,090 | 5,589 | 270 | 549 | 1,638 | 7,542 |
| Canada | 17,356 | 34,324 | 130,978 | 335,468 | 21,630 | 23,794 | 169,964 | 393,586 |
| Chile | 165 | 260 | 88 | 436 | 139 | 218 | 392 | 914 |
| Colombia | 134 | 544 | 173 | 1,537 | 6 | 20 | 313 | 2,101 |
| Germany, Federal Republic of | 99 | 760 | 1,894 | 10,296 | 5,881 | 5,894 | 7,874 | 16,950 |
| Hong Kong | 3,370 | 4,703 | 375 | 1,932 | 231 | 322 | 3,976 | 6,957 |
| Israel | 115 | 492 | 2,553 | 13,135 | 28 | 73 | 2,696 | 13,700 |
| Italy | 40 | 272 | 4,967 | 17,703 | 2,823 | 2,820 | 7,830 | 20,795 |
| Japan | 139,717 | 209,866 | 3,517 | 14,561 | 170,596 | 184,264 | 313,830 | 408,691 |
| Korea, Republic of | 21,166 | 28,784 | 976 | 4,369 | 1,168 | 1,400 | 23,310 | 34,553 |
| Mexico | 15,845 | 25,222 | 21,865 | 50,487 | 32,056 | 35,638 | 69,766 | 111,347 |
| Netherlands | 7,851 | 10,033 | 1,705 | 7,893 | 3,780 | 3,512 | 13,336 | 21,438 |
| Taiwan | 14,519 | 19,367 | 975 | 8,980 | 16,193 | 13,287 | 31,687 | 41,634 |
| United Kingdom | 113 | 702 | 21,774 | 49,296 | 208 | 274 | 22,095 | 50,272 |
| Venezuela | 66 | 274 | 8,782 | 22,771 | 2 | 3 | 8,850 | 23,048 |
| Other | [r]37,193 | [r]57,075 | [r]11,948 | [r]46,692 | [r]1,404 | [r]1,546 | 50,545 | 105,313 |
| Total | 259,598 | 396,798 | 215,811 | 600,945 | 258,404 | 275,686 | 733,813 | 1,273,429 |
| 1985: |  |  |  |  |  |  |  |  |
| Argentina | 38 | 150 | 132 | 828 | 57 | 41 | 227 | 1,019 |
| Australia | 227 | 600 | 1,110 | 5,605 | 24 | 37 | 1,361 | 6,242 |
| Belgium-Luxembourg | 55 | 39 | 513 | 2,956 | 2,934 | 2,555 | 3,502 | 5,550 |
| Brazil | 234 | 1,066 | 1,006 | 5,334 | 941 | 886 | 2,181 | 7,286 |
| Canada | 36,200 | 50,867 | 127,064 | 303,756 | 15,840 | 15,599 | 179,104 | 370,222 |
| Chile | 111 | 147 | 15 | 113 | 53 | 76 | 179 | 336 |
| Colombia | 33 | 118 | 1,598 | 3,766 | 21 | 333 | 1,652 | 4,212 |
| Germany, Federal Republic of | 288 | 856 | 1,556 | 9,833 | 4,844 | 4,342 | 6,688 | 15,031 |
| Hong Kong | 4,167 | 4,789 | 862 | 2,908 | 130 | 164 | 5,159 | 7,861 |
| Israel | 172 | 828 | 4,082 | 15,911 | 29 | 49 | 4,283 | 16,788 |
| Italy | 21 | 169 | 2,300 | 12,215 | 5,029 | 4,393 | 7,350 | 16,777 |
| Japan | 198,341 | 239,255 | 3,753 | 17,121 | 263,620 | 243,664 | 465,714 | 500,040 |
| Korea, Republic of | 21,065 | 24,729 | 1,485 | 4,420 | 783 | 770 | 23,333 | 29,919 |
| Mexico | 20,011 | 27,786 | 22,958 | 57,115 | 49,772 | 53,891 | 92,741 | 138,792 |
| Netherlands | 27,346 | 29,762 | 1,189 | 7,104 | 5,271 | 4,538 | 33,806 | 41,404 |
| Taiwan | 15,007 | 17,660 | 1,316 | 5,800 | 21,601 | 16,221 | 37,924 | 39,681 |
| United Kingdom | 1,414 | 2,170 | 2,923 | 17,046 | 1,581 | 1,556 | 5,918 | 20,772 |
| Venezuela | 50 | 285 | 5,091 | 13,807 | 2 | 5 | 5,143 | 14,097 |
| Other | 22,512 | 40,327 | 6,985 | 33,181 | 2,114 | 1,549 | 31,611 | 75,057 |
| Total | 347,292 | 441,598 | 185,938 | 518,819 | 374,646 | 350,669 | 907,876 | 1,311,086 |

[r] Revised.

[1] Includes castings, forgings, and unclassified semifabricated forms.

Source: Bureau of the Census.

### Table 12.—U.S. imports for consumption of aluminum, by class

| Class | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Crude and semicrude: |  |  |  |  |
| Metals and alloys, crude | 881,956 | $1,292,724 | 868,674 | $1,017,458 |
| Circles and disks | 13,219 | 31,672 | 11,764 | 25,130 |
| Plates, sheets, etc., n.e.c | 393,738 | 893,013 | 344,943 | 721,308 |
| Rods and bars | 46,531 | 90,337 | 63,714 | 86,162 |
| Pipes, tubes, etc | 4,074 | 12,609 | 3,348 | 14,876 |
| Scrap | 137,675 | 145,748 | 127,501 | 108,625 |
| Total | 1,477,193 | 2,466,108 | 1,419,944 | 1,973,554 |
| Manufactures: |  |  |  |  |
| Foil | 24,496 | 90,629 | 25,934 | 82,879 |
| Leaf | (1) | 108 | (1) | 108 |
| Flakes and powders | 4,673 | 8,601 | 4,480 | 7,593 |
| Wire | 3,017 | 6,633 | 4,238 | 8,123 |
| Total | 32,186 | 105,971 | 34,652 | 98,703 |
| Grand total | 1,509,379 | 2,572,074 | 1,454,596 | 2,072,257 |

[1] 1984—aluminum leaf not over 30.25 square inches in area, 1,375,995 leaves, and aluminum leaf over 30.25 square inches in area, 85,741,332 square inches; and 1985—aluminum leaf not over 30.25 square inches in area, 1,505,626 leaves, and aluminum leaf over 30.25 square inches in area, 68,118,504 square inches.

Source: Bureau of the Census.

## Table 13.—U.S. imports for consumption of aluminum, by country

| Country | Metals and alloys, crude |  | Plates, sheets, bars, etc.[1] |  | Scrap |  | Total |  |
|---|---|---|---|---|---|---|---|---|
|  | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1984: |  |  |  |  |  |  |  |  |
| Argentina | 8,859 | $13,226 | 4,936 | $10,357 | -- | -- | 13,795 | $23,583 |
| Australia | 2,329 | 3,749 | 25,921 | 59,152 | -- | -- | 28,250 | 62,901 |
| Bahrain | 39,141 | 30,587 | 288 | 461 | -- | -- | 39,429 | 31,048 |
| Belgium-Luxembourg | 948 | 1,389 | 29,781 | 56,210 | 1,731 | $2,058 | 32,460 | 59,657 |
| Brazil | 44,523 | 68,973 | 15,379 | 28,166 | -- | -- | 59,902 | 97,139 |
| Canada | 603,069 | 906,200 | 68,454 | 156,787 | 91,947 | 99,809 | 763,470 | 1,162,796 |
| Costa Rica | 19 | 42 | 1,115 | 2,176 | 56 | 82 | 1,190 | 2,300 |
| Germany, Federal Republic of | 12,335 | 25,277 | 15,841 | 43,054 | 398 | 406 | 28,574 | 68,737 |
| Israel | 1,280 | 1,762 | 1,503 | 6,424 | 165 | 240 | 2,948 | 8,426 |
| Italy | 1,715 | 2,184 | 11,519 | 25,358 | 895 | 1,247 | 14,129 | 28,789 |
| Japan | 356 | 1,368 | 134,385 | 315,666 | 66 | 81 | 134,807 | 317,115 |
| Mexico | 814 | 589 | 2,623 | 3,895 | 4,367 | 4,742 | 7,804 | 9,226 |
| Netherlands | 1,564 | 2,109 | 6,124 | 22,200 | 1,612 | 2,256 | 9,300 | 26,565 |
| South Africa, Republic of | 19,662 | 30,056 | 767 | 1,376 | 35 | 43 | 20,464 | 31,475 |
| Spain | 18,933 | 27,317 | 4,073 | 8,640 | -- | -- | 23,006 | 35,957 |
| United Arab Emirates | 34,160 | 51,807 | -- | -- | 5,033 | 367 | 39,193 | 52,174 |
| United Kingdom | 13,132 | 20,530 | 5,765 | 16,982 | 12,444 | 16,470 | 31,341 | 53,982 |
| Venezuela | 37,540 | 46,468 | 36,049 | 57,817 | 11,615 | 10,585 | 85,204 | 114,870 |
| Other | [r]41,577 | [r]59,091 | [r]93,039 | [r]212,910 | [r]7,311 | [r]7,362 | 141,927 | 279,363 |
| Total | 881,956 | 1,292,724 | 457,562 | 1,027,631 | 137,675 | 145,748 | 1,477,193 | 2,466,103 |

See footnotes at end of table.

## Table 13.—U.S. imports for consumption of aluminum, by country —Continued

| Country | Metals and alloys, crude |  | Plates, sheets, bars, etc.[1] |  | Scrap |  | Total |  |
|---|---|---|---|---|---|---|---|---|
|  | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1985: |  |  |  |  |  |  |  |  |
| Argentina | 25,307 | $29,471 | 4,515 | $7,308 | -- | -- | 29,822 | $36,779 |
| Australia | 1,346 | 1,752 | 15,401 | 32,792 | 26 | $70 | 16,773 | 34,614 |
| Bahrain | 12,403 | 15,520 | 1,081 | 1,099 | -- | -- | 13,484 | 16,619 |
| Belgium-Luxembourg | 935 | 1,433 | 33,006 | 48,769 | 509 | 469 | 34,450 | 50,671 |
| Brazil | 41,737 | 46,083 | 6,144 | 10,350 | -- | -- | 47,881 | 56,433 |
| Canada | 675,705 | 773,060 | 48,162 | 97,007 | 101,736 | 86,593 | 825,603 | 956,660 |
| Costa Rica | 18 | 31 | 159 | 262 | 71 | 41 | 248 | 334 |
| Germany, Federal Republic of | 3,219 | 11,302 | 17,783 | 43,589 | 646 | 598 | 21,648 | 55,489 |
| Israel | 1,494 | 1,672 | 2,442 | 9,916 | 326 | 295 | 4,262 | 11,883 |
| Italy | 42 | 43 | 10,385 | 18,738 | 252 | 214 | 10,679 | 18,995 |
| Japan | 1,660 | 2,817 | 143,815 | 329,232 | 4 | 7 | 145,479 | 332,056 |
| Mexico | 90 | 69 | 1,613 | 2,311 | 5,342 | 4,426 | 7,045 | 6,806 |
| Netherlands | 1,498 | 2,616 | 7,256 | 21,659 | 183 | 182 | 8,937 | 24,457 |
| South Africa, Republic of | 15,111 | 18,396 | 790 | 1,291 | 34 | 36 | 15,935 | 19,723 |
| Spain | 21,265 | 24,886 | 3,119 | 6,013 | 6 | 4 | 24,390 | 30,903 |
| United Arab Emirates | 29,304 | 36,037 | 621 | 753 | -- | -- | 29,925 | 36,790 |
| United Kingdom | 3,078 | 4,415 | 8,838 | 24,647 | 2,673 | 2,376 | 14,589 | 31,438 |
| Venezuela | 7,517 | 7,924 | 54,294 | 63,331 | 6,723 | 5,718 | 68,534 | 76,973 |
| Other | 26,945 | 39,926 | 64,345 | 128,409 | 8,970 | 7,596 | 100,260 | 175,931 |
| Total | 868,674 | 1,017,453 | 423,769 | 847,476 | 127,501 | 108,625 | 1,419,944 | 1,973,554 |

[r] Revised.

[1] Includes circles, disks, rods, pipes, tubes, etc.

Source: Bureau of the Census.

## WORLD REVIEW

World primary aluminum production capacity decreased slightly in 1985. Although there were significant reductions of annual capacity in Japan and the United States, they were offset by capacity expansions in Australia, Brazil, and Canada. Several other countries announced plans to increase annual primary smelter capacity within the next several years.

World production of primary aluminum fell slightly to 15.3 million tons in response to high metal inventories and lower prices. The United States led the world in reducing metal production. Several of the West European countries and Japan also lowered production, but their lower production was offset by increased production in Australia, Brazil, and Canada as new production capacity potlines were brought on-stream.

Primary aluminum inventories held by members of the International Primary Aluminum Institute (IPAI), which represent the bulk of the stocks held outside the centrally planned economy countries, decreased from 2.59 million tons at yearend 1984 to 2.18 million tons at yearend 1985. IPAI reported that total metal inventories, including secondary aluminum, was 3.96 million tons at yearend.

During 1985, two separate international conferences by independent aluminum producers met to discuss cooperation among countries in matters of common interest. Nine independent producers from Argentina, Bahrain, Brazil, Dubai, Egypt, Indonesia, Norway, Switzerland, and Venezuela met in Buenos Aires to discuss aluminum supply, demand, and pricing. The results of the meeting appeared to be some cooperation in regard to pricing of aluminum and the formation of a study group. In Cairo, the Second Arab Aluminum Conference (ARABAL 85) was attended by 12 Arab countries, India, and 11 European countries to discuss ways of maintaining or improving the Arab aluminum industry's competitiveness in world markets.

**Argentina.**—In July, Aluminios Argentinos S.A.I.C. (ALUAR) cut its production rate by 10,000 tons per year but increased its annual capacity by 6,000 tons to 146,000 tons in June and planned to increase annual capacity to 150,000 tons by February 1986.

**Australia.**—Alcan Australia Ltd. brought the third potline into commission at its Kurri Kurri smelter. The new 50,000-ton-per-year potline, which increased annual capacity to 140,000 tons, was completed in October 1984, but commissioning the potline was delayed owing to poor aluminum prices. However, about mid-1985, Alcan stated that the current value of the Australian dollar made production at the Kurri Kurri smelter competitive with world prices.

Partnership of the Portland, Victoria, aluminum smelter continued to change during the year. Alcoa of Australia Ltd. and the Victorian State government, the major partners, increased their shares of the smelter to 60% and 40% from their original 45% and 25%, respectively, when the Australian Commonwealth Superannuation Fund Investment Trust and Hyundai Corp., the Republic of Korea, decided against proposed stakes in the partnership. In September, First National Ltd., a banking arm of the National Australia Bank, agreed to take a 10% share in the smelter reducing both Alcoa's and the State government's shares by 5%. In October, the China International Trust and Investment Corp. agreed to take an additional 10% interest in the smelter. At yearend 1985, the proposed ownership of the 300,000-ton-per-year smelter project was Alcoa of Australia, 50%; Victoria State government, 30%; First National, 10%; and China International Trust, 10%. The first 150,000-ton-per-year potline was about 55% complete and was expected to come on-stream about November 1986. The second 150,000-ton-per-year potline was scheduled for startup in 1988.

The proposed 220,000-ton-per-year smelter project for Western Australia, sponsored by Reynolds, Griffin Coal Mining Co. Ltd., and the Western Australian government, was suspended indefinitely in 1985. The withdrawal of the fourth partner, Kukje Corp.-ICC Group of the Republic of Korea, left the group without a 50%-equity participant.

**Bahrain.**—Gulf Aluminum Rolling Mill Co. constructed a 40,000-ton-per-year computer-controlled aluminum foil rolling mill in Bahrain. The mill was sponsored by Bahrain, Iraq, Kuwait, Oman, Qatar, and Saudi Arabia, and major equipment will consist of a four-high reversing hot mill and a four-high nonreversing cold mill. Width of the mill was 1,751 millimeters.

**Belgium-Luxembourg.**—National Luxembourg Aluminium Co. (NLAC) increased its foil and casting capacity at its Dundelange plant by the installation of a continuous casting plant. It also increased its molten metal processing capacity in its casthouse by 20%. NLAC, which came on-stream early in 1985, is a subsidiary of the U.S.-based National Intergroup.

**Brazil.**—Cia. Brasileira de Alumínio (CBA) announced that it would increase the annual capacity of its Sorocaba, São Paulo, smelter to 340,000 tons by the end of the century. CBA increased annual capacity from 125,000 to 155,000 tons in 1985 and planned to increase capacity to 170,000 tons in 1986 and to 240,000 tons by 1990. CBA, a subsidiary of S.A. Indústria Votorantim is the only wholly Brazilian-owned producer of aluminum.

Consorcio de Alumínio Albras e Alunorte S.A. inaugurated its first 80,000-ton-per-year potline at the proposed 320,000-ton-per-year smelter in November 1985. The smelter is about 50 miles upstream of the mouth of the Amazon River (Belem). The project is 51% owned by the Brazilian Government, Cia. Vale do Rio Doce (CVRD), and 49% by a consortium of 33 Japanese companies, Nippon Amazon Aluminium Co. Differences between the two partners over pricing for aluminum remained unresolved at yearend, and there was some doubt whether the second stage of the project should proceed under current market conditions.

Vale do Sul Alumínio S.A.—jointly owned by CVRD (52%), Shell do Brasil S.A. (44%) (a subsidiary of Billiton Metais S.A.), and Reynolds (4%)—reportedly planned to expand its 86,000-ton-per-year Santa Cruz smelter another 90,000 to 110,000 tons per year. The plant came on-line in 1982, and provisions were made for adding two 90,000-ton-per-year-capacity sections in the original project.

In December, the Brazilian Government created a study task force to report on the possibility of ending the electric power discount to aluminum producers. Should the task force recommend ending the discount, future increases in Brazil's smelting capacity could be affected.

Reynolds reportedly was negotiating to construct a $50 million can production plant in Brazil. The plant was expected to have an annual capacity of about 800 million cans.

**Canada.**—Canadian Reynolds Metals Co. Ltd., a subsidiary of Reynolds, Richmond, VA, expanded the annual capacity of its Baie Comeau, Quebec, smelter from 159,000 to 272,000 tons in September at a cost of about $400 million. The North Plant expansion contained a potline of 240 cells in two parallel buildings and used the Pechiney 180,000-ampere-cell design with current fed to the cells at 1,000 volts. The cells were considered to be the most energy efficient and environmentally acceptable in the world. The 536 pots in the older South Plant were removed, rebuilt, and modernized with improved technology at a cost of $110 million. The original plant was built in 1957 and expanded in 1968. An agreement between the government of Quebec and Reynolds provided a reduction in power rates during the plant's first 5 years of operation.

Alcan Aluminium Ltd. and the Canadian Association of Smelter and Allied Workers at Alcan's Kitimet, British Columbia, 268,000-ton-per-year smelter signed a new labor agreement effective July 24, 1985. The 3-year contract called for some wage increases and some job security benefits.

Aluminiere de Bécancour Inc., jointly owned by Pechiney (50%), Alumax (25%), and Société Générale de Financement du Quebec (25%), announced that construction of the Bécancour smelter in Quebec was several months ahead of schedule and about $45 million below cost. The first potline of the 230,000-ton-per-year smelter was scheduled to begin operation about mid-1986, with the second 115,000-ton-per-year potline scheduled to begin operations in 1987.

Alcan announced the indefinite postponement of the greenfield Laterriere smelter at Chicoutimi, Quebec, owing to low metal prices and high metal inventories. The original project, announced in 1984, called for construction of a 250,000-ton-per-year smelter costing about $750 million.

Canadian Reynolds and American Can Canada Inc., a subsidiary of American Can Co., Greenwich, CT, formed a new company, Bevco, to market aluminum and steel beverage cans produced at American Can's existing Canadian can plants and Reynolds' U.S. can facilities. The Bevco partnership covers only beverage cans and will market 8-, 16-, and 32-ounce aluminum cans produced by Reynolds. In 1984, Reynolds announced that it may construct three canmaking plants in Quebec to utilize the metal from the Baie Comeau smelter expansion.

The government of Ontario, which had restricted beverage container materials to steel or glass, drafted new regulations that allowed other types of nonrefillable containers for beverages but only in tandem with a materials recovery program. The regulation also provided that refillable glass containers would be guaranteed a protected share of the market. Aluminum beverage can use in the Province was expected to utilize about 29,000 tons per year of aluminum.

**China.**—Construction began on a 200,000-ton-per-year aluminum smelter in Datong, Quinhai. The plant to be built in two phases that reportedly would coincide with construction of an alumina plant in Shanxi Province and a hydropowerplant on the Yellow River at Quinhai. The first 100,000 tons of annual capacity with a foundry and environmental control facilities was scheduled to come on-stream by yearend 1987.

The Japanese companies Nissho-Iwai Corp. and Nippon Light Metal Co. Ltd. reportedly have agreed to assist China in building an integrated aluminum smelting operation at Pingguo in the Guangxi region. The first phase of the project would be a 100,000-ton-per-year smelter with possible completion by 1987.

China was considering the purchase of Japan's idled 100,000-ton-per-year Toyo smelter from Sumitomo Aluminium Smelting Co. Ltd. as the first step in construction of a 200,000-ton-per-year smelter near Xian in Shaanxi Province. Another possible Japanese plant for the Xian project was part of the Ryoka Light Metal's 76,000-ton-per-year Sakaide smelter.

Davy McKee Corp., a United Kingdom engineering company, contracted to build a 6,000-ton-per-year aluminum foil rolling mill for China's Shanghai aluminum mill plant. It was expected to be completed by mid-1988.

**Colombia.**—Industrias Metalurgicas Unidas S.A. purchased Alcan Aluminium's 50% equity interest in Aluminio Alcan de Colombia S.A., a sheet rolling and extrusion facility. Industrias Metalurgicas already owned one-half of the fabrication facility.

**France.**—Pechiney delayed startup of its 89,000-ton-per-year St. Jean-de-Maurienne, Savoie, aluminum potline owing to poor market conditions. The potline, originally scheduled to begin in the fourth quarter of 1984, increased annual capacity of the smelter to 130,000 tons. In addition, Pechiney shut down 17,000 tons of old capacity at St. Jean and 20,000 tons at its l'Argentiere, Hautes-Alpes, smelter.

Pechiney will build a 3,500-ton-per-year aluminum-lithium (Al-Li) alloy foundry at its Issoire facility in central France. It will produce 1.5-ton Al-Li ingots for the aerospace industries. The plant was expected to come on-stream in late 1987 and may eventually be expanded to 12,000 tons of annual capacity.

Alusuisse and Pechiney signed an agreement to form a joint subsidiary to operate a facility to manufacture aluminum slugs for aerosol cans and soft tubes. Pechiney Cebal, a subsidiary of Pechiney, would have a 51% share in the company and Alusuisse, a 49% share of the plant at Alusuisse's Beaurepaise slug plant in Isère, France. The agreement also called for doubling the plant's annual capacity to 15,000 tons.

Alcoa sold its French soft alloy extrusion and anodizing mill at Châteauroux to Norsk Hydro A/S of Norway. Norsk Hydro reportedly would invest between $1.1 and $2.16 million to modernize the mill. The mill produced extrusions mainly for the construction industry and had an annual capacity of about 8,000 tons.

Électricité de France, a state-owned utility company, and Pechiney concluded an agreement to obtain a special fixed low price for 3 billion kilowatts of power annually for 10 years. Pechiney agreed to present Électricité with 2 billion francs worth of nonvoting securities, which pay dividends on Pechiney's corporate profit.

**Germany, Federal Republic of.**—Vereinigte Aluminium Werke AG (VAW) began construction of a foil rolling plant at Grevenbroich. The plant will consist of four fully automated computer-controlled foil mills with rolling speeds of 2,000 meters per minute and a foil width of 2,000 millimeters. The improved technology for the foil mills reportedly would increase productivity about 50% in comparison with world foil mill standards.

**Ghana.**—Volta Aluminium Co. (VALCO) restarted two of its five 40,000-ton-per-year potlines at the Tema smelter. The smelter, 90% owned by Kaiser and 10% by Reynolds, was shut down in 1983 owing to low water at the Akosombo Dam, which led to a curtailment of hydroelectric power. In 1985, VALCO and the Government of Ghana signed an agreement, after 2 years of negotiation, that increased the price VALCO would pay for power and restricted the amount of firm power provided annually to the smelter. Under abnormal conditions, power may be further curtailed in favor of Ghanian essential domestic requirements.

**Iceland.**—Icelandic Aluminium Co. Ltd. (ISAL), a subsidiary of Alusuisse, Switzerland, was considering plans to increase capacity at its 86,000-ton-per-year Straumsvik smelter to 130,000 tons. The China

National Nonferrous Industries Corp. discussed a 10% participation in the expansion with Alusuisse and the Icelandic Government.

**India.**—The new aluminum complex owned by National Aluminium Co. Ltd. (NALCO), a Government-owned company in Tolcher, Orissa, was expected to be commissioned in September 1986 with the startup of one of two 109,000-ton-per-year potlines. Reportedly, Hindustan Aluminium Co. Ltd., jointly owned by Kaiser and private interests, implemented a program to increase the annual capacity of the Renukoot, Uttar Pradesh, smelter from 120,000 to 150,000 tons per year.

**Italy.**—The Italian state-owned Ente Participazione Finanziamento Industria Manifattura (EFIM) postponed the closing of the 35,000-ton-per-year Bolzano smelter. New plans announced the closing of the 30,000-ton-per-year Porto Marghera smelter between 1987 and 1989.

**Japan.**—The Ministry of International Trade and Industry (MITI) agreed to reduce tariffs on aluminum plate, sheet, and strip from 11.5% ad valorem to 9.2% early in 1986, and further reduce the 9.3% tariff on these mill products to 3% and the 9% tariff on aluminum ingot to 1% effective January 1, 1988, with intermediate reductions April 1, 1987.

Showa Light Metal Co. Ltd., jointly owned by Showa Denko K.K. (50%) and Comalco of Australia (50%), announced the closing of its 59,000-ton-per-year Chiba smelter effective in May 1986.

Furukawa Electric Co. Ltd. purchased Alcoa's 13% share of the Furukawa Aluminium Co. Ltd., and aluminum semimanufacturing company. The purchase terminated Alcoa's minority joint interest in the manufacturing company from Alcoa's 33% interest 5 years ago, and increased Furukawa Electric's interest to 94%. The remaining shares of the Japan-based company are owned by the trading house C. Itoh & Co. Ltd.

**Korea, North.**—Reportedly, North Korea will operate an aluminum smelter at Pyong Kouk. Construction apparently started in 1984 with economic and technological assistance obtained from the U.S.S.R. A completion date was not available.

**Korea, Republic of.**—Pechiney, France, reportedly discussed sale of its 50% equity in Aluminium of Korea Ltd. (Koralu) to its partner Hyundai Industries, which would give Hyundai complete ownership. Koralu operates a 20,000-ton-per-year smelter at Ulson.

Mando Machinery Corp., Anyong, the Republic of Korea, and Ford Motor Co., Detroit, MI, reached an agreement to form a joint venture company to produce about 450,000 metal aluminum radiators for South Korean automakers. Mando was the leading manufacturer of automotive parts in the Republic of Korea.

**Mexico.**—Alcan Aluminium sold its 49% interest in Alcan Mexicana S.A. de C.V. to Aluminio S.A. de C.V., in which Alcoa holds a 44% interest. Alcan Mexicana was a holding company with three operating subsidiaries involved in aluminum semifabrication, building products and truck bodies, and marketing and fabrication.

**Netherlands.**—Hunter Douglas Ltd. Europe began installing an integrated cold mill strip annealing facility for heat-treated aluminum alloys in its Rotterdam plant. The new installation was not expected to increase the annual capacity but should modernize the plant and increase efficiency. The plant modernization would be completed by mid-1986.

**New Zealand.**—Comalco and the New Zealand Government reached an agreement for a new electric-power-pricing formula, based on the Pechiney Independent Price, to calculate power charges at the 244,000-ton-per-year Tiwai Point aluminum smelter. The new formula replaced Comalco's use of the Alcan World Price, which was discontinued in 1984. The future of the Tiwai Point smelter was in doubt after the Government increased electricity prices to the smelter by 25% on April 1. The smelter is jointly owned by Comalco (60%), Sumitomo Aluminium (20%), and Showa Light Metal (20%). Late in the year, the smelter was operating at about 12,000 tons below annual capacity owing to a pot attrition policy.

**Norway.**—Ardal og Sunndal Verk A/S (ASV Group), owned by the Government of Norway, planned to increase annual capacity at the Ardal plant from 187,000 to about 230,000 tons through modernization programs. Modernization of an old 22,000-ton-per-year potline, shut down in May, should increase the line to 44,000 tons per year. Improvements in the remaining sections of the plant were expected to raise the annual capacity to 220,000 tons. Using the company's own technology, modernization began on five pots with completion expected by late 1985.

Annual capacity of the Sör-Norge Aluminium A/S (Soral) 66,000-ton Huenes smelter was to be increased to 100,000 tons. The Huenes plant is owned by Alusuisse (75%) and Norsk Hydro (25%); however, following the expansion, Alusuisse's share would be reduced to 50%. The project should be completed about 2 years after necessary approvals are received.

Norsk Hydro's Karmöy Fobriskker announced plans to expand the Karmöy Island smelter from 160,000 to 210,000 tons per year by 1987. Technology developed by Pechiney would be used, and work was scheduled to begin in mid-1985. The smelter is owned by Norsk Hydro (49%) and the Government of Norway (51%).

Discussions between ASV Group and Norsk Hydro on a merger of the two organizations were continued throughout the year. By yearend, no agreement was reached owing to major differences on the type of joint venture organization. Merger of these two organizations could give the new company a total annual capacity of over 600,000 tons after expansions.

**Table 14.—Aluminum, primary: World production,[1] by country**

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina | 134 | 138 | 133 | 134 | 136 |
| Australia | 379 | 381 | 478 | 758 | [2]851 |
| Austria | [r]94 | 94 | 94 | 95 | [2]94 |
| Bahrain | [r]130 | 171 | 172 | 177 | 177 |
| Brazil | 256 | 299 | 401 | 455 | 540 |
| Cameroon | [r]65 | [r]79 | 77 | 73 | 75 |
| Canada | 1,116 | 1,065 | 1,091 | 1,227 | [2]1,282 |
| China[e] | [r]350 | 380 | [r]400 | [r]400 | 410 |
| Czechoslovakia | 33 | 34 | 36 | 32 | 32 |
| Egypt | 134 | 141 | 140 | 166 | 175 |
| France | 436 | 390 | 361 | 342 | [2]293 |
| German Democratic Republic[e] | 60 | 58 | 57 | 58 | 58 |
| Germany, Federal Republic of | 729 | 723 | 743 | 777 | 745 |
| Ghana | 190 | 174 | 42 | -- | 48 |
| Greece[3] | [r] [e]146 | [r] [e]135 | 136 | 136 | [2]123 |
| Hungary | 74 | 74 | 74 | 74 | [2]74 |
| Iceland | [r]74 | [r]75 | 76 | 80 | 74 |
| India[3] | 213 | 217 | 204 | 269 | 268 |
| Indonesia[3] | -- | [r]33 | 115 | 199 | 213 |
| Iran | [r]13 | 45 | 39 | 42 | 42 |
| Italy | 274 | 233 | 196 | 230 | [2]245 |
| Japan[4] | 771 | 351 | 256 | 287 | 227 |
| Korea, North[e] | 10 | 10 | 10 | 10 | 10 |
| Korea, Republic of[3] | 18 | 15 | 13 | 18 | 18 |
| Mexico[3] | 43 | 41 | 40 | 44 | 43 |
| Netherlands | 262 | 251 | 235 | 249 | 253 |
| New Zealand | 154 | [r]163 | 219 | 243 | 240 |
| Norway[5] | 634 | [r]638 | 715 | 761 | [2]724 |
| Poland[6] | 66 | 43 | 44 | 46 | [2]47 |
| Romania[5] | [r]242 | 208 | 223 | 215 | 220 |
| South Africa, Republic of | [r]84 | [r]106 | 161 | 167 | 168 |
| Spain | 397 | 367 | 358 | 381 | [2]370 |
| Suriname[7] | 41 | [r]43 | 34 | [r] [e]23 | 23 |
| Sweden[5] | 83 | 79 | 82 | 83 | [2]84 |
| Switzerland | 82 | 75 | 76 | 79 | [2]73 |
| Taiwan[3] | 31 | 10 | -- | -- | -- |
| Turkey | 40 | [r]36 | 30 | 38 | 38 |
| U.S.S.R.[e] | 1,800 | 1,875 | 2,000 | 2,100 | 2,200 |
| United Arab Emirates: Dubai | 106 | 149 | 151 | 155 | 155 |
| United Kingdom | 339 | 241 | 252 | 288 | [2]275 |
| United States | 4,489 | 3,274 | 3,353 | 4,099 | [2]3,500 |
| Venezuela | 314 | 274 | 335 | 386 | 396 |
| Yugoslavia[3] | 173 | [r]220 | 258 | 268 | 270 |
| Total | [r]15,079 | [r]13,408 | 13,910 | 15,664 | 15,289 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] The Bureau of Mines defines primary aluminum as "The weight of liquid aluminum as tapped from pots, excluding the weight of any alloying materials as well as that of any metal produced from either returned scrap or remelted materials." International reporting practices vary from country to country, some nations conforming to the foregoing definition and others using different definitions. For those countries for which a different definition is given specifically in the source publication, that definition is provided in this table by footnote. Table includes data available through June 3, 1986.

[2] Reported figure.

[3] Primary ingot.

[4] Excludes high-purity aluminum containing 99.995% or more as follows, in metric tons: 1981—6,222; 1982—4,345; 1983—2,679; 1984—4,358; and 1985—4,783.

[5] Primary unalloyed metal plus primary alloyed metal, thus including weight of alloying material.

[6] Primary unalloyed ingot plus secondary unalloyed ingot.

[7] Data represent exports of ingot aluminum, presumably all primary.

**Spain.**—Empresa Nacional del Alúminio S.A. (ENDASA) and Alúminio de Galicia S.A. (ALUGASA) were merged into one new company known as ENDASA. The new company will be owned by the Spanish state holding company Instituto Nacional de Industria (INI) (72%), Alcan (23%), and Spanish banks (5%). Pechiney sold its 37% interest in ALUGASA to INI in April, and Alcan had a 36% interest in ENDASA prior to the merger. Following the merger, the shutdown of the 25,000-ton-per-year Valladolid smelter was begun, and one-half of the 20,000-ton-per-year "Series I" installation at the 100,000-ton-per-year Avilés smelter was closed, with the remaining one-half scheduled for closure in 1985. The closure would leave the new Spanish company with about 338,000 tons of annual aluminum capacity.

**Sweden.**—Gränges Aluminium AB began operation of a new 20,000-ton-per-year UBC scrap remelting and rolling plant at Finspang to produce can body stock. The plant had an annual capacity to produce up to 15,000 tons of can stock and was built to achieve Sweden's goal of a 75% aluminum can recycling rate. Material from the plant would be mainly for Sweden's domestic consumption.

### Table 15.—Aluminum: World capacity, by continent and country[1]

(Thousand metric tons)

| Continent and country | 1983 | 1984 | 1985 |
|---|---|---|---|
| North America: | | | |
| Canada | 1,234 | 1,234 | 1,347 |
| Mexico | 45 | 45 | 45 |
| United States | 4,996 | [r]4,896 | 4,706 |
| South America: | | | |
| Argentina | 140 | 140 | 146 |
| Brazil | 419 | 519 | 629 |
| Suriname | 60 | 60 | 60 |
| Venezuela | 400 | 400 | 400 |
| Europe: | | | |
| Austria | 92 | 92 | 92 |
| Czechoslovakia | 60 | 60 | 60 |
| France | 378 | 333 | 333 |
| German Democratic Republic | 85 | 85 | 85 |
| Germany, Federal Republic of | 772 | 777 | 777 |
| Greece | 145 | 145 | 145 |
| Hungary | 76 | 76 | 76 |
| Iceland | 86 | 86 | 86 |
| Italy | 276 | 276 | 276 |
| Netherlands | 266 | 266 | 266 |
| Norway | [r]770 | [r]770 | 770 |
| Poland | 55 | 110 | 110 |
| Romania | 250 | 250 | 250 |
| Spain | 389 | 389 | 379 |
| Sweden | 82 | 82 | 82 |
| Switzerland | 86 | 86 | 86 |
| U.S.S.R | 2,320 | 2,490 | 2,550 |
| United Kingdom | 287 | 287 | 287 |
| Yugoslavia | 357 | 357 | 357 |
| Africa: | | | |
| Cameroon | 80 | 80 | 80 |
| Egypt | 166 | 166 | 170 |
| Ghana | 200 | 200 | 200 |
| South Africa, Republic of | 172 | 172 | 172 |
| Asia: | | | |
| Bahrain | 170 | 170 | 170 |
| China | [r]413 | [r]413 | 413 |
| India | 363 | 363 | 363 |
| Indonesia | 150 | 225 | 225 |
| Iran | 50 | 50 | 50 |
| Japan | 712 | 712 | 425 |
| Korea, North | 20 | 20 | 20 |
| Korea, Republic of | 18 | 18 | 18 |
| Taiwan | 50 | 50 | 50 |
| Turkey | 60 | 60 | 60 |
| United Arab Emirates: Dubai | 149 | 149 | 149 |
| Oceania: | | | |
| Australia | 594 | 812 | 862 |
| New Zealand | 244 | 244 | 244 |
| Total | [r]17,737 | [r]18,215 | 18,071 |

[r] Revised.

[1] Detailed information on the individual aluminum reduction plants is available in a 2-part report that can be purchased from Chief, Division of Finance, Bureau of Mines, Bldg. 20, Federal Center, Denver, CO 80225. Part 1 of "Primary Aluminum Plants, Worldwide" details location, ownership, and production capacity for 1983-90 and sources of energy and aluminum raw materials for foreign and domestic primary aluminum plants, including those in centrally planned economy countries. Part 2 summarizes production capacities for 1983-90 by smelter and country.

**Switzerland.**—Allegedly, an environmentalist group took responsibility for a bomb attack on the Usine d'Aluminium Martigny S.A. 10,000-ton-per-year smelter at Martigny. The plant was expected to be idled up to 6 months after the March attack. The attack was aimed at a power facility to be constructed on the Rhône River.

**United Kingdom.**—To increase casting capacity, British Alcan Aluminium Ltd. announced plans to build new casting facilities with associated furnaces at its 125,000-ton-per-year Lynemouth primary smelter. The company also started a program to convert Lynemouth's smelting pots to automatic feeding of raw materials. The conversion was expected to take about 5 years.

Alcan Enfield Alloys was expected to close one of its two United Kingdom-based secondary aluminum plants. The plant, the London Colney works, had an annual capacity of 20,000 tons. Operations at the plant would be transferred to the secondary smelter at Bradford.

**Venezuela.**—Construction began at the Industria Venezolana de Aluminio C.A. (VENALUM), San Felix, Guayana, smelter to increase annual capacity by 30,000 tons to 310,000 tons. The smelter, owned 80% by the Government and 20% by six Japanese companies, would be modernized by improving the efficiency of the existing potlines rather than by the addition of pots.

**Yugoslavia.**—The Government company, Boris Kidric Tvornica Glirice Aluminja, announced plans to modernize and expand the 50,000-ton-per-year smelter at Kedricevo, Slovenio. The expansion to 70,000 tons per year was expected to be completed by 1990.

**Zaire.**—A consortium, led by Alusuisse, decided to postpone the Aluzaire aluminum project at Banana, Cabinda. Lack of progress by the Zairian Government to establish infrastructure support for the 210,000-ton-per-year smelter was the major factor in the decision to abandon the project.

## TECHNOLOGY

Development of Al-Li alloys continued during the year.[5] Both domestic and foreign aluminum producers began production of Al-Li alloys, and several of the producers announced plans to construct commercial production facilities. Evaluation of the alloys in the form of extrusions, forgings, and sheets were being conducted by the major aerospace companies. The use of these alloys could reduce the weight of a large commercial aircraft by as much as 15%, thus, increasing the payload and decreasing fuel consumption.

Metal matrix composites (MMC), using aluminum combined with fibers, whiskers, or particles of oxides, carbides, and nitrides, impart strengths up to 10 times the strength of aluminum and stiffness up to twice that of steel. Densities of most aerospace MMC were about one-third that of steel. MMC materials can be used in aerospace applications because of their large weight reductions of up to 50%. Fabrication of MMC to near final shapes reduces machine wastes. The advantages and disadvantages of MMC were discussed.[6]

The effects of surface oxides on the mechanical properties and microstructure of high-strength corrosion-resistant and high-temperature aluminum powder metallurgy (PM) alloys were investigated.[7] Oxide surface layers, when incompletely broken up or nonuniformly distributed during consolidation of the particles, detrimentally affect the mechanical properties of the metal. Breakup of the surface oxides depends on the dehydration and constitual changes that occur during degassing of the powder.

An investigation on the effect of different fluoride additions on the vaporization of cryolite indicated that there is a relationship between the cationic radius of the fluoride added and the vapor pressure of the liquid cryolite.[8] Other parameters that influence the total vapor pressure above the melts are the bath temperature, the acidity of the bath owing to aluminum fluoride ($AlF_3$) additions, and the amount of lithium fluoride (LiF) and aluminum oxide ($Al_2O_3$). The catalytic effect of fluorides on the $Al_2O_3$ phase transformation, and the formation of the crust in aluminum cells was studied.[9] Commercial alumina was heat treated with additions of 2 weight percent of different fluorides and ranked according to the effect of the fluorides on the transformation temperature of the $Al_2O_3$ phase. The coherence of the alumina-network crusts was explained.

Several investigations were conducted on the electrolysis of aluminum chloride ($AlCl_3$) electrolyte for production of aluminum. Using bench scale cells, the effects of $AlCl_3$ concentration, convection, electrode spacing, and current density on the cell voltage, current efficiencies, and power efficiencies of the cell was investigated during the electrolysis of $AlCl_3$ in lithium chloride-sodium chloride (LiCl-NaCl) fused salt electrolytes at 700° C employing graphite electrodes.[10] Energy consumption was about 4.03 kW•h per pound of metal compared with an average of 7.5 kW•h per pound in the Hall-Heroult cell. The kinetics of aluminum deposition from NaCl-$AlCl_3$ melts in alumina crucibles was investigated at 820° C by linear sweep voltometry and potential step amperometry.[11] At a low $AlCl_3$ mole concentration (0.4 mole percent), the reduction of $AlCl_3$ on liquid aluminum was found to be diffusion controlled. At higher concentrations, passivation, apparently caused by precipitation of alumina from the supersaturated melt in the diffusion layer of the aluminum cathode, was observed during the deposition reaction.

Titanium diboride ($TiB_2$) material for use as electrodes in aluminum smelting cells continued to be investigated. Carbon pipes with a chemically vapor-deposited $TiB_2$ coating 700 micrometers thick were tested for corrosion and/or erosion resistance in a laboratory aluminum smelting cell for 100 hours.[12] Projected lifetime of the coating was only 30 days because of grain boundary attack with subsequent crystal pullout. As part of an inert electrode material study, the electrical resistivity of monocrystalline and polycrystalline $TiB_2$ was measured under an inert atmosphere by a four-point alternating current impedance technique over the range from 298° K to 1,373° K.[13] Values for 69%-dense and 99%-dense polycrystalline and for monocrystalline $TiB_2$ were determined.

Over a dozen papers on the processing, recovery, and recycling of scrap aluminum were published.[14] Several papers addressed the melting of low-density scrap, such as foil and beverage cans and can sheet scrap. Other papers addressed the recycling of UBC scrap and the design of recycling facilities. A plenary lecture presented an overview of the Bureau of Mines research on the recycling of minerals and metals.[15]

Studies by the Bureau of Mines on the development of new methods of purifying metal by fractionating multicomponent molten metal scrap by filtration were described.[16] One method was the separation of liquid and crystalline phases formed by addition of a component to produce a solid phase. Data for the purification of aluminum by the addition of titanium and boron to form $TiB_2$ were given. The chemistry and properties of salts used as fluxes for recycling aluminum were investigated.[17] Most of the salts fall within the six component system, sodium chloride-potassium chloride-aluminum chloride-sodium fluoride-potassium fluoride-aluminum fluoride (NaCl-KCl-$AlCl_3$-NaF-KF-$AlF_3$) with NaCl-KCl, KCl-$AlF_3$, and NaCl-$AlF_3$ as the stable binary systems. Twelve subsolidus compatability tetrahedra were determined by X-ray analysis. The technique for separating cast aluminum alloys from wrought alloys exploiting the difference in mechanical properties of the two types of alloys at elevated temperature was described.[18] Between 520° C and 580° C, casting alloys become brittle and can be fragmentized and separated from wrought alloys. Above 600° C, the wrought alloys also become brittle and efficiency of separation decreases. Separation is almost 100% when in the solidus temperature range of the casting alloys.

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[1] All quantities in this chapter are given in metric tons unless otherwise indicated.

[2] Physical scientist, Division of Nonferrous Metals.

[3] U.S. Department of Energy, Bonneville Power Administration. Direct Service Industry Options Final Environmental Impact Statement (EIS). DOE/EIS-0123F, Apr. 1986, 241 pp.

[4] American Metal Market. 33.1B Units Recycled in '85: Aluminum Assoc. V. 94, No. 78, Apr. 22, 1986, p. 9.

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# Antimony

## By Patricia A. Plunkert[1]

The production of primary antimony products decreased slightly compared with that of 1984 as a result of a general softening of demand in the antimony market. Imports for consumption were also down from those of 1984. In September, the General Services Administration (GSA) completed the sale of excess antimony metal from the National Defense Stockpile (NDS).

**Domestic Data Coverage.**—Domestic production data for antimony are developed by the Bureau of Mines from two voluntary surveys of U.S. operations. Typical of these surveys is the "Primary Antimony" survey. Of the 10 operations to which a survey request was sent, all responded, representing 100% of the primary smelter production shown in table 1 and 100% of the total antimony content of primary antimony production by class shown in table 3.

**Table 1.—Salient antimony statistics**

(Short tons of antimony content unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production: | | | | | |
| Primary: | | | | | |
| Mine (recoverable antimony) | 646 | 503 | 838 | 557 | W |
| Smelter[1] | 17,844 | 12,282 | 14,557 | [r]17,639 | 16,449 |
| Secondary | 19,856 | 16,596 | 14,204 | [r]14,823 | 13,572 |
| Exports of metal, alloys, waste and scrap | 324 | 830 | 304 | 511 | 362 |
| Exports of antimony oxide | 375 | 277 | 365 | 480 | 885 |
| Imports for consumption | 17,970 | 13,387 | 12,885 | 23,089 | 20,694 |
| Reported industrial consumption, primary antimony[1] | 11,592 | 9,414 | 10,418 | [r]12,465 | 11,701 |
| Stocks: Primary antimony, all classes, Dec. 31 | 9,158 | 5,973 | 3,935 | [r]6,895 | 6,033 |
| Price: Average, cents per pound[2] | 135.5 | 107.2 | 91.3 | 151.2 | 131.1 |
| World: Mine production | [r]63,510 | [r]61,131 | 55,880 | [p]60,396 | [e]60,621 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Includes primary antimony content of antimonial lead produced at primary lead refineries.

[2]New York dealer price for 99.5% to 99.6% metal, c.i.f. U.S. ports.

**Legislation and Government Programs.**—On September 20, the Environmental Protection Agency issued final regulations under the Clean Water Act for nonferrous metals manufacturing operations that limit the discharge of pollutants into navigable waters and into publicly owned treatment works. The primary antimony subcategory, 1 of 25 subcategories covered by this regulation, set limits on effluent discharges from both new and existing primary antimony plants that generate process wastewaters. Daily and monthly average maximums on the antimony, arsenic, and mercury content of effluents emanating from these plants were specified. The compliance date for existing plants was September 20, 1988.[2]

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Public Law 96-510), commonly known as the Superfund, expired on September 30, 1985. At yearend, various reauthorization bills, such as S-51 passed by the Senate on September 26 and HR-2817 passed by the House of Representatives on December 10, were under consideration by the Congress.

On September 18, GSA completed its latest sale of excess antimony metal from the NDS. Of the 1,000 short tons of metal authorized for disposal by Public Law 98-525 during fiscal year 1985, a total of 997 tons was sold. The total sale of excess antimony metal during calendar year 1985 was 928 tons. Any future sales of antimony from the stockpile will require additional legislative authority. GSA reported that yearend Government stocks of antimony metal in the NDS totaled 37,843 tons of stockpile-grade material. The stockpile goal remained at 36,000 tons.

On July 8, the White House announced that the President had approved the National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the NDS would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict that would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of materials already possessed by the Government. Antimony was included in tier I of this proposal with a gcal of 4,585 tons. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, stated that no action may be taken before October 1, 1986, to implement or administer any change in a stockpile goal in effect on October 1, 1984, that results in a reduction in the quality or quantity of any strategic and critical material to be acquired for the NDS.

## DOMESTIC PRODUCTION

### MINE PRODUCTION

Sunshine Mining Co. produced antimony as a byproduct of the treatment of tetrahedrite, a complex silver-copper-antimony sulfide, one of the principal ore minerals in the Kellogg, ID, area. United States Antimony Corp.'s (USAC) antimony mining operation at Thompson Falls, MT, was closed during 1985.

Antimony was also produced by ASARCO Incorporated as a byproduct of the smelting of some domestic lead ores.

**Table 2.—Antimony mine production and shipments in the United States**

(Short tons of recoverable antimony)

| Year | Produced | Shipped |
|---|---|---|
| 1981 | 646 | 590 |
| 1982 | 503 | 365 |
| 1983 | 838 | 878 |
| 1984 | 557 | 711 |
| 1985 | W | W |

W Withheld to avoid disclosing company proprietary data.

### SMELTER PRODUCTION

**Primary.**—Production of primary antimony products decreased compared with that of 1984 owing to a decrease in demand.

Amspec Chemical Corp. announced that it planned to add a second antimony furnace to its plant in Gloucester City, NJ. The new furnace reportedly would enable the company to produce antimony trioxide from a greater variety of raw materials including ores, crude oxide, and metal. Installation was scheduled to be completed by May 1986.

Anzon America Inc. announced that it was upgrading its antimony facilities in Laredo, TX, in order to make the plant more flexible. The planned addition of a new blast furnace reportedly would increase plant capacity and enable the company to use a wider range of feed materials. In addition to improving its production facilities, the company also announced that it was moving downstream into consumption with the acquisition of a New Jersey plastics firm, Monmouth Plastics Inc., which produced flame retardant materials, the major use for antimony trioxide.

The other producers of primary antimony products were: Asarco, Omaha, NE, and El Paso, TX; Chemet Co., Moscow, TN; Laurel Industries Inc., La Porte, TX; McGean Chemical Co. Inc., Cleveland, OH; M & T Chemicals Inc., Baltimore, MD; Sunshine Mining, Kellogg, ID; and USAC, Thompson Falls, MT.

### Table 3.—Primary antimony produced in the United States

(Short tons of antimony content)

| Year | Class of material produced | | | | Total |
|---|---|---|---|---|---|
| | Metal | Oxide | Residues | Byproduct antimonial lead | |
| 1981 | 790 | 16,425 | 83 | 546 | 17,844 |
| 1982 | 539 | 11,564 | 179 | W | 12,282 |
| 1983 | 1,121 | 13,153 | 283 | W | 14,557 |
| 1984 | 1,113 | $^{r}$16,379 | 147 | W | $^{r}$17,639 |
| 1985 | 943 | 15,398 | 108 | W | 16,449 |

$^{r}$Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

**Secondary.**—Old scrap, predominantly lead battery plates, was the source of most of the secondary output. New scrap, mostly in the form of drosses and residues from various sources, supplied the remainder. The antimony content of scrap was usually recovered and consumed as antimonial lead.

### Table 4.—Secondary antimony produced in the United States, by kind of scrap and form of recovery

(Short tons of antimony content unless otherwise specified)

| | 1984$^{r}$ | 1985 |
|---|---|---|
| KIND OF SCRAP | | |
| New scrap: Lead- and tin-base | 1,326 | 1,184 |
| Old scrap: Lead- and tin-base | 13,497 | 12,388 |
| Total | 14,823 | 13,572 |
| FORM OF RECOVERY | | |
| In antimonial lead | 13,862 | 12,456 |
| In other lead- and tin-base alloys | 961 | 1,116 |
| Total | 14,823 | 13,572 |
| Value (millions) | $44.8 | $35.6 |

$^{r}$Revised.

## CONSUMPTION AND USES

Reported domestic consumption of primary antimony decreased compared with that of 1984 but remained slightly above the average 11,000 tons per year of material consumed during the previous 5-year period. Antimony compounds were used in plastics both as stabilizers and as flame retardants. Antimony stabilizers were used to retard heat and light degradation in plastics such as polyvinyl chloride. Antimony trioxide in an organic solvent was used to make fabrics, plastics, and other combustibles flame retardant. Antimony was also used as a decolorizing and refining agent in some types of glass such as special optical glass.

Antimony metal alloyed with lead was used in lead-acid storage batteries, industrial chemical pumps and pipes, tank linings, roofing sheets, and cable sheaths. In these alloys, antimony increases strength and inhibits chemical corrosion. In 1985, the Battery Council International reported that the total domestic shipments of replacement and original equipment automotive batteries in the United States were about the same as those of 1984. However, there were about 360,000 less units exported in 1985.

### Table 5.—Reported industrial consumption of primary antimony in the United States

(Short tons of antimony content)

| Year | Class of material consumed: Metal | Oxide | Sulfide | Residues | Byproduct antimonial lead | Total |
|---|---|---|---|---|---|---|
| 1981 | 1,546 | 9,885 | 32 | 83 | 546 | 11,592 |
| 1982 | 1,282 | 7,924 | 29 | 179 | W | 9,414 |
| 1983 | 1,245 | 8,867 | 23 | 283 | W | 10,418 |
| 1984 | [r]1,543 | 10,747 | 28 | 147 | W | [r]12,465 |
| 1985 | 1,507 | 10,053 | 33 | 108 | W | 11,701 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

### Table 6.—Reported industrial consumption of primary antimony in the United States, by product

(Short tons of antimony content)

| Product | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Metal products: | | | | | |
| Ammunition | 409 | 294 | 175 | W | 410 |
| Antimonial lead | 1,257 | 793 | 926 | 845 | 568 |
| Bearing metal and bearings | 206 | 143 | 143 | [r]182 | 179 |
| Cable covering | 24 | 25 | 31 | W | W |
| Castings | 11 | 9 | 9 | 11 | 11 |
| Collapsible tubes and foil | 9 | 1 | W | W | W |
| Sheet and pipe | 36 | 26 | 43 | 80 | W |
| Solder | 105 | 124 | 154 | [r]232 | 338 |
| Type metal | 19 | 11 | 10 | 31 | 31 |
| Other | 69 | 67 | 71 | 337 | 105 |
| Total | 2,145 | 1,493 | 1,562 | [r]1,718 | 1,642 |
| Nonmetal products: | | | | | |
| Ammunition primers | 25 | 20 | 16 | 21 | 27 |
| Ceramics and glass | 782 | 1,358 | 1,252 | 1,292 | 1,187 |
| Fireworks | 4 | 6 | 4 | 7 | 4 |
| Pigments | 341 | 330 | 198 | 178 | 147 |
| Plastics | 1,551 | 1,050 | 993 | 1,108 | 998 |
| Rubber products | 232 | 221 | 70 | 21 | 25 |
| Other | 111 | 103 | 119 | [r]161 | 141 |
| Total | 3,046 | 3,088 | 2,652 | [r]2,788 | 2,529 |
| Flame-retardant: | | | | | |
| Adhesives | 585 | 179 | 184 | 343 | 310 |
| Paper | 131 | 103 | 133 | 159 | 111 |
| Pigments | 40 | 25 | 14 | 8 | 8 |
| Plastics | 4,509 | 3,312 | 4,441 | 5,858 | 5,529 |
| Rubber | 174 | 104 | 220 | 342 | 315 |
| Textiles | 962 | 1,110 | 1,212 | 1,249 | 1,257 |
| Total | 6,401 | 4,833 | 6,204 | 7,959 | 7,530 |
| Grand total | 11,592 | 9,414 | 10,418 | [r]12,465 | 11,701 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

### Table 7.—Industry stocks of primary antimony in the United States, December 31

(Short tons of antimony content)

| Stocks | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Antimonial lead[1] | 117 | W | W | W | W |
| Metal | 916 | 556 | 805 | [r]582 | 800 |
| Ore and concentrate | 2,529 | 532 | 446 | 1,304 | 1,164 |
| Oxide | 4,707 | 4,711 | 2,614 | 4,926 | 3,954 |
| Residues and slags | 864 | 150 | 51 | 69 | 99 |
| Sulfide | 25 | 24 | 19 | 14 | 16 |
| Total | 9,158 | 5,973 | 3,935 | [r]6,895 | 6,033 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1] Inventories from primary sources at primary lead refineries only.

## PRICES

The New York dealer price for imported antimony metal was $1.35 to $1.40 per pound at the beginning of the year. The price fluctuated throughout the year and reached a high of $1.42 to $1.47 per pound at the end of March. At yearend, the dealer price was listed at $1.28 to $1.32 per pound.

Asarco's published price for high-tint antimony trioxide in lots of 40,000 pounds was $1.65 per pound at the beginning of the year. The price was reduced several times during the year and reached a low of $1.45 per pound in September. Asarco's published price remained at this level through yearend. Other domestic producers also adjusted their prices during the year to remain competitive with generally lower priced imported material.

Metal Bulletin (London) published European price quotations for antimony ore and concentrates. Both prices decreased steadily throughout the year. At yearend, the quotations were as follows: clean sulfide concentrates, 60% antimony content, $20.50 to $24.00 per metric ton unit (equivalent to $18.60 to $21.75 per short ton unit), and lump sulfide ore, 60% antimony content, $23.00 to $26.00 per metric ton unit (equivalent to $20.85 to $23.60 per short ton unit).

**Table 8.—Antimony price ranges in 1985, by type**

| Type | Price per pound |
|---|---|
| Domestic metal[1] | $2.00 |
| Foreign metal[2] | $1.20- 1.47 |
| Antimony trioxide[3] | 1.45- 1.65 |

[1] Based on antimony in alloy.
[2] Duty-paid delivery, New York.
[3] Producer price, published by ASARCO Incorporated, for high-tint antimony trioxide.

## FOREIGN TRADE

Exports of antimony oxide increased significantly and reached their highest level since 1967, the year the Bureau of Mines began reporting this data. In addition to exports of antimony oxide, the United States also exported 1,582 tons (gross weight) of other antimony compounds with a value of $4.7 million. Approximately 45% of these compounds was shipped to the Federal Republic of Germany, and the balance was divided among 26 other countries.

Total imports of antimony materials decreased compared with those of 1984, led by a 40% decrease in imports of antimony oxide. China remained the principal source of imported material and increased its share of total U.S. antimony imports from 34% in 1984 to approximately 40% in 1985.

In 1985, a few source countries for antimony metal and oxide were eligible for special duty-free status under the Generalized System of Preferences, namely, Bolivia, Brazil, Hong Kong, Mexico, and Peru.[8]

**Table 9.—U.S. exports of antimony metal, alloys, waste and scrap, by country**

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Gross weight (short tons) | Value (thousands) | Gross weight (short tons) | Value (thousands) |
| Australia | 41 | $129 | -- | -- |
| Belgium | -- | -- | 99 | $242 |
| Canada | 20 | 33 | 2 | 10 |
| Dominican Republic | 9 | 14 | 4 | 15 |
| Germany, Federal Republic of | 2 | 3 | 2 | 3 |
| India | -- | -- | 59 | 223 |
| Italy | 19 | 25 | -- | -- |
| Japan | 21 | 45 | 48 | 34 |
| Korea, Republic of | 19 | 15 | -- | -- |
| Mexico | 24 | 67 | 41 | 103 |
| Netherlands | 60 | 168 | 11 | 30 |
| Spain | -- | -- | 28 | 41 |
| Taiwan | 223 | 127 | -- | -- |
| Trinidad | 5 | 11 | -- | -- |
| United Kingdom | 5 | 19 | 21 | 76 |
| Venezuela | 28 | 150 | 1 | 2 |
| Other | 36 | 111 | 46 | 97 |
| Total[1] | 511 | 915 | 362 | 876 |

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## Table 10.—U.S. exports of antimony oxide, by country

| Country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Gross weight (short tons) | Antimony content[1] (short tons) | Value (thousands) | Gross weight (short tons) | Antimony content[1] (short tons) | Value (thousands) |
| Australia | 80 | 66 | $348 | 4 | 3 | $15 |
| Canada | 98 | 81 | 248 | 368 | 305 | 1,051 |
| Germany, Federal Republic of | 57 | 47 | 123 | 123 | 102 | 260 |
| Israel | 18 | 15 | 16 | 2 | 2 | 4 |
| Italy | 83 | 69 | 316 | 139 | 115 | 538 |
| Japan | 69 | 57 | 157 | 25 | 21 | 78 |
| Korea, Republic of | 3 | 2 | 12 | 7 | 6 | 57 |
| Mexico | 28 | 23 | 92 | 59 | 49 | 87 |
| Netherlands | 21 | 17 | 62 | 3 | 2 | 6 |
| Singapore | 36 | 30 | 112 | 4 | 3 | 12 |
| United Kingdom | 53 | 44 | 113 | 308 | 256 | 677 |
| Venezuela | 16 | 13 | 55 | 6 | 5 | 24 |
| Other | 14 | 12 | 40 | 19 | 16 | 67 |
| Total[2] | 578 | 480 | 1,693 | 1,067 | 885 | 2,876 |

[1] Estimated by the Bureau of Mines.

[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## Table 11.—U.S. import duties for antimony

| Item | TSUS No. | Most favored nation (MFN) | | Non-MFN |
|---|---|---|---|---|
| | | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Ore | 601.03 | Free | Free | Free. |
| Needle or liquated | 603.10 | 0.1 cent per pound | 0.1 cent per pound | 0.25 cent per pound. |
| Metal, unwrought | 632.02 | .3 cent per pound | Free | 2 cents per pound. |
| Antimony oxide | 417.50 | .1 cent per pound | do | Do. |

## Table 12.—U.S. imports for consumption of antimony, by class and country

| Country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Gross weight (short tons) | Antimony content[1] (short tons) | Value (thousands) | Gross weight (short tons) | Antimony content[1] (short tons) | Value (thousands) |
| Antimony ore and concentrate: | | | | | | |
| Bolivia | 1,923 | 1,253 | $2,016 | 973 | 642 | $1,349 |
| Canada | 18 | 9 | 11 | 756 | 421 | 406 |
| Chile | 319 | 188 | 279 | 429 | 276 | 486 |
| China | 270 | 158 | 249 | 4,555 | 1,798 | 5,144 |
| Guatemala | -- | -- | -- | 655 | 320 | 391 |
| Honduras | 192 | 96 | 119 | 273 | 150 | 223 |
| Hong Kong | 61 | 25 | 56 | 22 | 14 | 25 |
| Malaysia | -- | -- | -- | 55 | 17 | 25 |
| Mexico | 3,976 | 970 | 1,288 | 4,000 | 2,055 | 1,948 |
| Peru | 139 | 84 | 160 | -- | -- | -- |
| Singapore | -- | -- | -- | 1,727 | 661 | 1,754 |
| South Africa, Republic of | 1,075 | 596 | 1,079 | -- | -- | -- |
| Taiwan | -- | -- | -- | 450 | 90 | 94 |
| Thailand | 1,918 | 920 | 1,541 | 443 | 181 | 406 |
| United Kingdom | -- | -- | -- | 43 | 13 | 130 |
| Total | 9,891 | 4,299 | 6,798 | 14,381 | 6,638 | 12,381 |
| Antimony oxide: | | | | | | |
| Belgium-Luxembourg | 591 | 491 | 1,513 | 607 | 504 | 1,549 |
| Bolivia | 1,206 | 1,001 | 1,981 | 685 | 569 | 1,325 |
| Brazil | -- | -- | -- | 92 | 76 | 194 |
| Canada | 101 | 84 | 10 | 19 | 16 | 65 |
| Chile | 61 | 51 | 76 | -- | -- | -- |
| China | 5,983 | 4,966 | 13,612 | 3,404 | 2,825 | 8,789 |
| France | 1,721 | 1,428 | 4,615 | 1,436 | 1,191 | 5,134 |
| Germany, Federal Republic of | 123 | 102 | 609 | 97 | 80 | 653 |

See footnotes at end of table.

## Table 12.—U.S. imports for consumption of antimony, by class and country —Continued

| Country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Gross weight (short tons) | Antimony content[1] (short tons) | Value (thousands) | Gross weight (short tons) | Antimony content[1] (short tons) | Value (thousands) |
| Antimony oxide —Continued | | | | | | |
| Hong Kong | 174 | 144 | $384 | 482 | 401 | $1,281 |
| Italy | 59 | 49 | 117 | -- | -- | -- |
| Japan | 3 | 2 | 60 | 7 | 6 | 35 |
| Korea, Republic of | -- | -- | -- | 20 | 17 | 68 |
| Netherlands | 20 | 17 | 42 | -- | -- | -- |
| South Africa, Republic of | 7,463 | 6,194 | 2,207 | 3,534 | 2,933 | 785 |
| Switzerland | -- | -- | -- | 31 | 26 | 126 |
| Taiwan | 20 | 17 | 36 | -- | -- | -- |
| U.S.S.R | 44 | 37 | 66 | -- | -- | -- |
| United Kingdom | 315 | 261 | 1,020 | 206 | 171 | 761 |
| Total | 17,884 | 14,844 | 26,348 | 10,620 | 8,815 | 20,765 |
| Antimony sulfide:[2] | | | | | | |
| Austria | 2 | 1 | 15 | -- | -- | -- |
| Belgium-Luxembourg | 11 | 7 | 30 | 6 | 4 | 15 |
| Canada | -- | -- | -- | 10 | 7 | 17 |
| China | 37 | 26 | 47 | 126 | 84 | 187 |
| Germany, Federal Republic of | 2 | 1 | 20 | 1 | 1 | 10 |
| Ivory Coast | -- | -- | -- | 24 | 16 | 26 |
| Japan | -- | -- | -- | (3) | (3) | 1 |
| South Africa, Republic of | 20 | 13 | 45 | -- | -- | -- |
| Total | 72 | 48 | 157 | 167 | 112 | 256 |

[1] Antimony ore and concentrate content reported by Bureau of the Census. Antimony oxide and antimony sulfide content estimated by the Bureau of Mines.

[2] Includes needle or liquated.

[3] Less than 1/2 unit.

Source: Bureau of the Census.

## Table 13.—U.S. imports for consumption of antimony metal, by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Gross weight (short tons) | Value (thousands) | Gross weight (short tons) | Value (thousands) |
| Belgium-Luxembourg | 257 | $282 | 1 | $4 |
| Bolivia | 357 | 552 | -- | -- |
| Canada | 5 | 235 | 1 | 175 |
| Chile | 79 | 198 | -- | -- |
| China | 2,641 | 6,208 | 3,398 | 8,617 |
| France | -- | -- | (1) | 4 |
| Germany, Federal Republic of | 1 | 64 | (1) | 30 |
| Hong Kong | -- | -- | 228 | 601 |
| Japan | (1) | 12 | (1) | 6 |
| Mexico | 467 | 365 | 1,247 | 1,006 |
| Peru | 33 | 42 | 101 | 205 |
| Spain | 17 | 28 | 58 | 150 |
| Taiwan | -- | -- | 95 | 185 |
| U.S.S.R | 19 | 34 | -- | -- |
| United Kingdom | 22 | 17 | -- | -- |
| Total | 3,898 | 8,037 | 5,129 | 10,983 |

[1] Less than 1/2 unit.

Source: Bureau of the Census.

## WORLD REVIEW

**Canada.**—In June, Durham Resources Inc. reported that production of antimony concentrates had resumed at its Lake George Mine in New Brunswick. At full capacity, the mill reportedly could process 100,000 tons per year of ore averaging 4.15% antimony. Shaft extension to the new ore zone at the mine was completed and development work on the ore body continued. The new ore zone, underlying the original ore body that reportedly was depleted in 1981, was estimated to contain about 850,000 tons of ore.

**China.**—Amspec announced that it had signed a letter of intent with numerous Chinese Government agencies to construct an antimony plant similar to Amspec's facility in Gloucester City, NJ. Reportedly, the plant would be situated in Yiyan, Hunan, and have an annual capacity of 3,000 to 5,000 tons of antimony oxide. Construction was expected to start within a couple of years.[4]

**Guatemala.**—Minas de Guatemala S.A. announced the reopening of its Annabella and Los Lirios antimony-tungsten mines after a 4-year shutdown. Production levels of 33 tons per day of antimony ore, grading 3.5% antimony, were reported. The company expected production levels to increase to 83 tons per day by yearend 1985.

**Japan.**—Antimony trioxide production, mainly from imported material, was 9,087 tons, a decrease of 15% compared with 1984 production levels. Antimony metal production increased from 279 tons in 1984 to 326 tons in 1985.[5]

In October, Dowa Mining Co. Ltd. announced the start of antimony trioxide production at its Kosaka smelter. The company reportedly planned to increase its production levels from the initial 22 tons of antimony trioxide per month to 44 tons per month in January 1986. The company also announced plans to begin production of sodium antimonate from imported raw material in the near future.[6]

### Table 14.—Antimony: World mine production (content of ore unless otherwise specified), by country[1]

(Short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Australia[2] | 1,241 | 1,263 | 592 | 1,014 | 1,100 |
| Austria | 665 | 735 | 726 | 687 | 660 |
| Bolivia | 16,866 | 15,408 | 10,969 | 10,231 | 9,500 |
| Brazil | [r]68 | -- | -- | -- | -- |
| Burma | [e]110 | -- | -- | -- | -- |
| Canada[3] | 1,840 | -- | -- | 610 | 1,205 |
| China[e] | 11,000 | 13,200 | 16,500 | 16,500 | 16,500 |
| Czechoslovakia | 805 | 770 | 990 | 1,100 | 1,100 |
| France | 344 | 340 | 122 | -- | -- |
| Guatemala[e] | [4]563 | 550 | -- | 100 | 220 |
| Honduras[e] | 22 | -- | -- | 350 | 440 |
| Italy | 767 | 374 | -- | 269 | [4]546 |
| Malaysia (Sarawak) | 211 | 153 | 148 | 19 | 20 |
| Mexico[5] | 1,984 | 1,725 | 2,777 | 3,377 | 3,300 |
| Morocco | [r]565 | 998 | 500 | 1,071 | 1,100 |
| Pakistan | 22 | ([6]) | ([6]) | 1 | -- |
| Peru (recoverable) | 755 | 814 | 786 | 741 | 720 |
| South Africa, Republic of (content of concentrates) | 10,814 | [7]10,070 | [7]6,947 | 8,201 | 8,150 |
| Spain | 712 | 506 | 539 | 643 | 635 |
| Thailand | 1,322 | 734 | 1,315 | 2,172 | 2,250 |
| Turkey | 924 | 1,189 | 926 | 1,121 | 1,100 |
| U.S.S.R.[e] | 9,500 | 9,900 | 10,000 | 10,300 | 10,400 |
| United States[8] | 646 | 503 | 838 | 557 | W |
| Yugoslavia | 1,604 | 1,672 | 1,047 | [r] [e]1,050 | 1,400 |
| Zimbabwe | 160 | 227 | 158 | 282 | 275 |
| Total | [r]63,510 | [r]61,131 | 55,880 | 60,396 | 60,621 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1] Table includes data available through May 27, 1986.

[2] Antimony content of antimony ore and concentrates, lead concentrates, and lead-zinc concentrates.

[3] Partly estimated on the basis of reported value of total production.

[4] Reported figure.

[5] Antimony content of ores for export plus antimony content of antimonial lead and other smelter products produced.

[6] Revised to zero.

[7] Reported figure from Consolidated Murchison Ltd. 1983 Annual Report.

[8] Production from antimony mines; excludes amount produced as a byproduct of domestic lead ores.

**Mexico.**—Anzon America Inc. and Cía. Minera y Refinadora Mexicana S.A. announced plans to install a new concentrator for low-grade ore at their mine in Wadley, Mexico. Upon completion, production capacity was expected to be increased by 1,100 tons of concentrate per year.

**Thailand.**—BP Minerals International Ltd., Siam Cement Co., and the Government of Thailand announced the formation of a joint venture company, Associated Minerals Co. Ltd., to explore and eventually mine antimony deposits in the Bor Thong District of Chonburi Province. Exploration was expected to commence by yearend.[7]

## TECHNOLOGY

General Electric Co. announced the fabrication of indium-antimonide infrared sensor arrays, using an epitaxial process, that exhibited significantly improved sensitivity. The new type of sensors, which can be operated at reportedly higher temperatures than bulk-type indium-antimonide sensors, permit the use of passive cooling techniques in space applications. The sensors were fabricated at the company's Electronics Laboratory in Syracuse, NY.[8]

Fujitsu Ltd. of Japan announced the recent development of a new material for erasable optical disks. The material, which was coated with a thin film of selenium-indium-antimony alloy, was reportedly stable in both the recording and erasing modes. A 20-centimeter diameter disk made of this material had a reported memory capacity of one gigabyte, about 600 times that of an 8-inch floppy disk. Fujitsu announced that it planned to commercialize the disk, together with a disk drive unit, within 2 to 3 years.[9]

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[1] Physical scientist, Division of Nonferrous Metals.

[2] Federal Register. U.S. Environmental Protection Agency. Nonferrous Metals Manufacturing Point Source Category; Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards. V. 50, No. 183, Sept. 20, 1985, pp. 38276-38402.

[3] U.S. International Trade Commission. Tariff Schedules of the United States Annotated 1985, 3rd Supplement. USITC Publ. 1610, Sept. 1, 1985, varying pagination.

[4] Metal Bulletin (London). Chinese Sign Antimony Plant Contract. No. 6979, Apr. 19, 1985, p. 15.

[5] Japan Metal Journal. V. 16, No. 10, Mar. 24, 1986, p. 6.

[6] ———. V. 15, No. 60, Dec. 16, 1985, p. 10.

[7] Industrial Minerals (London). Antimony Joint-Venture Signed. No. 214, July 1985, pp. 13, 15.

[8] Aviation Week and Space Technology. V. 123, No. 9, Sept. 2, 1985, p. 91.

[9] Japan Chemical Week. Fujitsu Develops New Material for Erasable Optical Disc. V. 26, No. 1298, Feb. 14, 1985, p. 9.

# Asbestos

## By Robert L. Virta[1]

U.S. apparent consumption of asbestos declined in 1985. Shipments from domestic mines remained unchanged while imports for consumption decreased 32% from those of 1984. Adverse publicity on asbestos-related health risks and a proposed Environmental Protection Agency (EPA) ban of certain asbestos products contributed to the poor market conditions in the United States.

**Domestic Data Coverage.**—Domestic production data for asbestos are developed by the Bureau of Mines by means of a voluntary industry survey. Of the three canvassed operations to which a survey request was made, all responded, representing 100% of the total production data shown in table 1.

**Table 1.—Salient asbestos statistics**

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production (sales): | | | | | |
| Quantity metric tons | 75,618 | 63,515 | 69,906 | 57,422 | 57,457 |
| Value[1] thousands | $30,685 | $24,917 | $27,866 | $24,238 | $20,485 |
| Exports and reexports (unmanufactured): | | | | | |
| Quantity metric tons | 64,419 | 58,771 | 54,634 | 39,919 | 45,656 |
| Value thousands | $21,508 | $19,713 | $19,683 | $18,346 | $16,489 |
| Exports and reexports of asbestos products: | | | | | |
| Value do | $145,130 | $127,867 | $129,582 | $163,347 | $193,765 |
| Imports for consumption (unmanufactured): | | | | | |
| Quantity metric tons | 337,618 | 241,737 | 196,387 | 209,963 | 142,431 |
| Value thousands | $103,893 | $64,925 | $57,956 | $64,749 | $44,093 |
| Consumption[2] metric tons | 348,800 | 246,500 | 217,000 | 226,000 | 162,000 |
| World: Production do | [r]4,349,466 | [r]4,036,213 | 4,178,660 | [p]4,105,884 | [e]4,111,298 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]F.o.b. mine.

[2]Calculated as the total of U.S. beginning stocks plus production plus imports minus ending stocks and exports.

**Legislation and Government Programs.**—On February 1, 1985, the EPA announced that occupational safety and consumer risks associated with asbestos would be referred to the Occupational Safety and Health Administration (OSHA) and the Consumer Product Safety Commission under section 9 of the Toxic Substances Control Act (TSCA).[2] This action was reviewed by the House Energy and Commerce Subcommittee on Oversight and Investigations. As a result of the investigation, EPA halted the referral plan on March 8, 1985.

The EPA proposed a temporary rule to limit asbestos exposures for State and local government employees who were not covered by OSHA regulations or by State plans adopted under the Occupational Safety and Health Act.[3] The ruling specifies that the average asbestos exposure for workers engaged in the removal, enclosure, or encapsulation of any material containing more than 1% asbestos by weight cannot exceed 2 fibers per cubic centimeter per 8-hour work period.

The EPA proposed a rule to establish Recommended Maximum Contaminant Levels (RMCL) for synthetic organic chemicals, inorganic chemicals, and microbiological parameters in drinking water.[4] Asbestos was included under the inorganic chemicals category. The proposal recommends establishing a RMCL for asbestos fibers exceeding 10 micrometers in length.

On December 13, the EPA submitted to the Office of Management and Budget a proposal to immediately ban the manufacture, importation, and processing of certain asbestos construction materials (asbestos cement pipe and fittings, roofing felts, flooring felts, felt back sheet floorings, vinyl asbestos floor tile, and asbestos clothing) under section 6 of the 1976 TSCA.[5] In addition, the mining and importation of asbestos and importation of asbestos products not directly banned would be placed under a permit system. The permit system would limit the mining and importation of asbestos to 30% of the 1981, 1982, and 1983 average values and would phase out asbestos use within 10 years.

OSHA continued to review a proposed standard for occupational exposure to asbestos.[6] The two permissible exposure limits to airborne asbestos being considered, 0.2 fiber per cubic centimeter or 0.5 fiber per cubic centimeter, would be a reduction from the existing asbestos exposure standard of 2 fibers per cubic centimeter per 8-hour work period.

Stockpile goals for asbestos were unchanged from those of 1984.

**Table 2.—Stockpile goals and Government inventories for asbestos as of December 31**

(Metric tons)

| | Stockpile goals | Total inventories | | |
|---|---|---|---|---|
| | | 1983 | 1984 | 1985 |
| Amosite | 15,422 | 38,591 | 30,855 | 30,855 |
| Chrysotile | 2,722 | 9,753 | 9,754 | 9,772 |
| Crocidolite | -- | 754 | 33 | 33 |
| Total | 18,144 | 49,098 | 40,642 | 40,660 |

Source: General Services Administration, Federal Property Service.

**Environmental Impact.**—Fifty asbestos producers and insurance companies agreed to establish an asbestos claims facility in the United States.[7] The facility will settle asbestos liability claims with the objective of avoiding long and costly litigations. Only about one-third of the $1 billion spent on asbestos compensation cases in the past 10 years has been paid to the claimants.

In 1985, the EPA awarded $45 million in grants and loans for controlling asbestos hazards in schools. Funds were authorized by the Asbestos School Hazard Abatement Act of 1984. Approximately $600 million is to be distributed to local jurisdictions for asbestos abatement over a 7-year period.

The State of New Jersey enacted legislation limiting asbestos exposure during the removal of asbestos from buildings to 330 nanograms per cubic centimeter (approximately 0.01 fiber per cubic centimeter).[8] The purpose of the regulation was to prevent improper or unnecessary removal of asbestos materials from buildings.

## DOMESTIC PRODUCTION

Mine shipments were unchanged in quantity but decreased 15% in value from those of 1984. The decrease in value was due primarily to a depressed market and high producer inventories.

Asbestos was produced in three mines in California and Vermont. Calaveras Asbestos Ltd. in California was the leading U.S. producer of asbestos, followed by Calidria Corp. and Vermont Asbestos Group Inc. Calidria, a subsidiary of Union Carbide Corp., was sold to a private investor group and renamed KCAC Inc.[9]

**Table 3.—Asbestos producers in the United States in 1985**

| State and company | County | Mine | Type of asbestos |
|---|---|---|---|
| California: | | | |
| Calaveras Asbestos Ltd | Calaveras | Copperopolis | Chrysotile. |
| Calidria Corp | San Benito | Santa Rita | Do. |
| Vermont: Vermont Asbestos Group Inc | Orleans | Lowell | Do. |

## CONSUMPTION AND USES

Total U.S. asbestos consumption decreased 28%. Approximately 92% of the asbestos consumed was chrysotile and 3% was crocidolite. Small amounts of amosite were reported used. Chrysotile grade 7 was most commonly used, followed by grades 4, 6, and 5. Spinning grades 1, 2, and 3 represented approximately 1% of the total consumption.

The end-use pattern for chrysotile presented in table 4 has been estimated from data supplied by U.S. producers and the Asbestos Institute in Quebec in cooperation with the Government of Canada. The data account for 92% of the asbestos consumed.

**Table 4.—U.S. asbestos consumption by end use, grade, and type**

(Thousand metric tons)

| End use | Chrysotile[1] | | | | | | | Amosite | Crocidolite | Other[2] | Total asbestos |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grades 1 and 2 | Grade 3 | Grade 4 | Grade 5 | Grade 6 | Grade 7 | Total | | | | |
| 1984 total | 0.1 | 2.0 | 25.1 | 21.7 | 17.4 | 153.6 | 219.9 | 0.4 | 5.7 | -- | 226.0 |
| 1985: | | | | | | | | | | | |
| Asbestos-cement pipe | -- | -- | 16.8 | 1.9 | 4.5 | -- | 23.2 | -- | 4.8 | -- | 28.0 |
| Asbestos-cement sheet | -- | -- | -- | (3) | 3.9 | 2.7 | 6.6 | -- | -- | -- | 6.6 |
| Coatings and compounds | -- | -- | -- | -- | -- | 23.1 | 23.1 | -- | -- | -- | 23.1 |
| Flooring products | -- | -- | -- | -- | -- | 7.0 | 7.0 | -- | -- | -- | 7.0 |
| Friction products | -- | .2 | .5 | 6.5 | 4.0 | 22.7 | 33.9 | -- | -- | -- | 33.9 |
| Insulation: | | | | | | | | | | | |
| Electrical | -- | -- | .1 | -- | -- | .3 | .4 | .1 | -- | -- | .5 |
| Thermal | -- | -- | (3) | (3) | -- | -- | .1 | -- | -- | -- | .1 |
| Packing and gaskets | -- | .2 | .6 | 3.3 | .3 | 2.0 | 6.4 | -- | -- | -- | 6.4 |
| Paper | -- | -- | -- | -- | .5 | 16.3 | 16.8 | -- | -- | -- | 16.8 |
| Plastics | -- | -- | -- | .1 | -- | .6 | .7 | -- | -- | -- | .7 |
| Roofing products | -- | -- | -- | (3) | .5 | 25.7 | 26.2 | -- | -- | -- | 26.2 |
| Textiles | -- | 1.2 | (3) | -- | -- | -- | 1.2 | -- | -- | -- | 1.2 |
| Other | .1 | .1 | .8 | .2 | (3) | 3.6 | 4.8 | .2 | -- | -- | 5.0 |
| Total | .1 | 1.7 | 18.8 | [4]12.1 | 13.7 | 104.0 | 150.4 | .3 | 4.8 | 7.3 | [5]155.5 |

[1] Estimated distribution based upon data provided by the Asbestos Institute, Montreal, Canada, and the Bureau of Mines, asbestos producer survey.

[2] Bureau of the Census.

[3] Less than 1/10 unit.

[4] Data do not add to total shown because of independent rounding.

[5] Does not include "Other" category in total. "Other" contains unspecified fiber type and end use.

## PRICES

Depressed markets and high producer inventories of the last few years have caused negotiated asbestos prices to be lower than listed prices. The average unit value of domestically produced asbestos in 1985 was $357 per metric ton. The average unit value of exported asbestos was $361 per ton.

**Table 5.—Customs unit values of imported asbestos**

(Dollars per metric ton)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Canada: | | | | | |
| Chrysotile: | | | | | |
| Cement | 272 | 234 | 257 | 284 | -- |
| Crude | -- | 380 | 199 | 1,084 | 576 |
| Spinning | 927 | 917 | 932 | 699 | 731 |
| Other | 373 | 334 | 384 | 431 | 283 |
| South Africa, Republic of: | | | | | |
| Amosite | 728 | 771 | 840 | 869 | 830 |
| Crocidolite | 676 | 646 | 629 | 705 | 569 |

Source: Bureau of the Census.

## FOREIGN TRADE

There was a 16% increase in the total value of asbestos fibers and asbestos products exported from the United States. The asbestos fiber portion was 8% of total value. Exports of brake linings and disk pads accounted for 75% of the value of all asbestos products exported. It is the only export category that increased in value from that of 1984. Canada remained the largest importer of U.S. asbestos fibers and products, followed by Japan, Mexico, Brazil, and Venezuela.

Canada provided 92% of the asbestos imported into the United States, and the Republic of South Africa provided 8%. Several other countries provided minor amounts. Approximately 91% of asbestos fiber imports were chrysotile. The value of imported asbestos fiber decreased 32%.

### Table 6.—Countries importing U.S. asbestos fibers and products

(Thousand dollars)

| Country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Unmanufactured fibers | Manufactured products | Total | Unmanufactured fibers | Manufactured products | Total |
| Australia | 55 | 2,457 | 2,512 | 1 | 1,379 | 1,380 |
| Brazil | 215 | 3,683 | 3,898 | 251 | 3,592 | 3,843 |
| Canada | r888 | 112,012 | r112,900 | 714 | 148,663 | 149,377 |
| Germany, Federal Republic of | 1,023 | 2,540 | 3,563 | 75 | 1,948 | 2,023 |
| Japan | 3,279 | 9,062 | 12,341 | 3,294 | 10,140 | 13,434 |
| Korea, Republic of | 479 | 1,259 | 1,738 | 190 | 1,814 | 2,004 |
| Kuwait | 31 | 857 | 888 | 31 | 437 | 468 |
| Mexico | 6,997 | 4,649 | 11,646 | 6,261 | 6,483 | 12,744 |
| Saudi Arabia | 4 | 4,904 | 4,908 | 2 | 1,409 | 1,411 |
| Thailand | 1,916 | 179 | 2,095 | 2,330 | 332 | 2,662 |
| Turkey | 13 | 350 | 363 | -- | 544 | 544 |
| United Kingdom | 192 | 619 | 811 | 50 | 926 | 976 |
| Venezuela | 571 | 3,975 | 4,546 | 267 | 3,487 | 3,754 |
| Other | 2,557 | 16,144 | 18,701 | 2,900 | 12,325 | 15,225 |
| Total[1] | 18,221 | 162,690 | 180,911 | 16,366 | 193,479 | 209,845 |

rRevised.

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

### Table 7.—U.S. exports and reexports of asbestos and asbestos products

| Products | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| EXPORTS | | | | | | |
| Unmanufactured: | | | | | | |
| Crudes, fibers, stucco metric tons | 40,476 | $14,879 | 26,381 | $14,106 | 29,382 | $12,705 |
| Sand and refuse do | 13,760 | 4,519 | 13,398 | 4,115 | 15,693 | 3,661 |
| Total do | 54,236 | 19,398 | 39,779 | 18,221 | 45,075 | 16,366 |
| Manufactured: | | | | | | |
| Asbestos fibers do | 1,537 | 5,198 | 958 | 5,067 | 607 | 3,793 |
| Brake linings and disk brake pads do | NA | 70,456 | NA | 103,308 | NA | 144,262 |
| Clutch facings and linings number | NA | 20,235 | NA | 23,206 | NA | 20,718 |
| Gaskets metric tons | 337 | 2,196 | 275 | 1,815 | 78 | 900 |
| Insulation do | NA | 3,270 | NA | 5,720 | NA | 4,566 |
| Packing and seals do | 1,015 | 10,174 | 1,150 | 9,063 | 1,192 | 6,716 |
| Shingles and clapboard do | 3,082 | 1,935 | 2,098 | 1,615 | 984 | 893 |
| Other articles of asbestos do | 4,953 | 5,598 | 1,759 | 2,595 | 1,521 | 2,437 |
| Other articles, n.s.p.f do | NA | 9,477 | NA | 10,306 | NA | 9,191 |
| Total | XX | 128,584 | XX | 162,690 | XX | 193,476 |

See footnotes at end of table.

### Table 7.—U.S. exports and reexports of asbestos and asbestos products —Continued

| Products | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity | Value (thousands) | Quantity | Value (thousands) | Quantity | Value (thousands) |
| **REEXPORTS** |  |  |  |  |  |  |
| Unmanufactured: |  |  |  |  |  |  |
| Crudes and fibers ____ metric tons__ | 333 | $271 | 140 | $125 | 369 | $71 |
| Sand and refuse ____ do____ | 65 | 14 | -- | -- | 212 | 52 |
| Total ____ do____ | 398 | 285 | 140 | 125 | 581 | 123 |
| Manufactured: |  |  |  |  |  |  |
| Asbestos fibers ____ do____ | 8 | 7 | 1 | 5 | (1) | 3 |
| Brake linings and disk brake pads ____ do____ | NA | 318 | NA | 47 | NA | 103 |
| Clutch facings and linings ____ number__ | NA | 167 | NA | 194 | NA | 73 |
| Gaskets ____ metric tons__ | (1) | 117 | 46 | 136 | 1 | 18 |
| Insulation ____ do____ | NA | 10 | (1) | 10 | NA | 8 |
| Packing and seals ____ do____ | 1 | 10 | (1) | 1 | 4 | 63 |
| Other articles of asbestos ____ do____ | 59 | 203 | NA | 264 | NA | 20 |
| Other articles, n.s.p.f ____ do____ | NA | 166 | -- | -- | NA | 1 |
| Total ____ | XX | 998 | XX | 657 | XX | 289 |

NA Not available. XX Not applicable.

[1] Less than 1/2 unit.

Source: Bureau of the Census.

### Table 8.—U.S. imports for consumption of asbestos fibers, by type, origin, and value

| Type | Canada |  | South Africa, Republic of |  | Other |  | Total |  |
|---|---|---|---|---|---|---|---|---|
|  | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1983 ____ | 184,303 | $49,733 | 11,754 | $7,740 | 330 | $483 | 196,387 | $57,956 |
| 1984: |  |  |  |  |  |  |  |  |
| Amosite ____ | -- | -- | 715 | 621 | -- | -- | 715 | 621 |
| Chrysotile: |  |  |  |  |  |  |  |  |
| Crude ____ | 85 | 92 | -- | -- | -- | -- | 85 | 92 |
| Spinning fibers | 2,041 | 1,369 | -- | -- | 93 | 123 | 2,134 | 1,492 |
| All other ____ | 193,525 | 54,806 | 7,541 | 3,423 | 307 | 326 | 201,373 | 58,555 |
| Crocidolite (blue) __ | -- | -- | 5,656 | 3,989 | -- | -- | 5,656 | 3,989 |
| Total ____ | 195,651 | 56,267 | 13,912 | 8,033 | 400 | 449 | 209,963 | 64,749 |
| 1985: |  |  |  |  |  |  |  |  |
| Amosite ____ | -- | -- | 121 | 100 | -- | -- | 121 | 100 |
| Chrysotile: |  |  |  |  |  |  |  |  |
| Crude ____ | 94 | 86 | 174 | 100 | -- | -- | 268 | 187 |
| Spinning fibers | 1,990 | 1,454 | -- | -- | 90 | 110 | 2,080 | 1,564 |
| All other ____ | 127,307 | 36,045 | 522 | 301 | 37 | 16 | 127,866 | 36,362 |
| Crocidolite (blue) __ | -- | -- | 4,794 | 2,726 | -- | -- | 4,794 | 2,726 |
| Other (unspecified asbestos type) ___ | 1,728 | 962 | 5,374 | 1,997 | 200 | 196 | 7,302 | 3,155 |
| Total ____ | 131,119 | 38,547 | 10,985 | 5,224 | 327 | 322 | 142,431 | [1]44,098 |

[1] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

World production of asbestos increased slightly from that of 1984. The major production changes occurred in Canada, where shipments were down 95,000 tons, and in the U.S.S.R., where production was estimated to be 100,000 tons greater than that of 1984. The U.S.S.R. remained the largest producer of asbestos, followed by Canada, the Republic of South Africa, Zimbabwe, Italy, China, and Brazil.

Depressed economic conditions and adverse publicity on asbestos-related health risks have contributed to poor market conditions, limited growth in asbestos production, and resulted in a decrease in exploration and development.

There were temporary shutdowns in several mining operations in Canada. In addition, four mining companies are forming a partnership to improve their position in the market. Many companies were delaying expansion of their operations until the effects of the proposed EPA asbestos ban on future markets are known. Expanding markets for asbestos were in the Far East and in developing countries.

**Australia.**—The New South Wales (NSW) State government rejected the Woodsreef Mines Ltd. application to extract 25 million tons of asbestos from mine tailings at its plant near Barraba.[10] Woodsreef Mines had received approval from the Australian Government to extract asbestos from mine tailings using a wet process. The NSW Minerals Resources Department was not satisfied with the safety provisions of the mining project.

**Canada.**—Four Canadian asbestos producers, Asbestos Corp. Ltd., Bell Asbestos Mines Ltd., Campbell Resources Inc., and Lac d'Amiante du Quebec, signed a memorandum of intent to form a partnership that would strengthen their resources and improve their position in domestic and export markets.[11] All four companies operated mines in the Thetford area of Quebec. The partnership would control over 50% of the asbestos output in Quebec. Earlier in 1985, Asbestos Corp. had devalued the book value of its Asbestos Hill Mine in northern Quebec and suspended operations indefinitely at the Thetford Mines' Quebec plant. Under the partnership, three mines and two of five processing mills owned by the four companies will be closed. Approximately 725 of the 2,225 employees will be dismissed, and production will be limited to 300,000 tons of chrysotile per year.

**China.**—A new asbestos dressing plant for concentrating ore began operation at Mangnai in Qinghai Province.[12] This plant has a production capacity of 12,000 tons per year. The construction of a second plant was being considered for the Province, where reserves are estimated at 20 million tons.

**Cyprus.**—Asbestos was produced from one mine in the Troodos Massif. The mine is operated by Cyprus Asbestos Mines Ltd. Prior to 1985, Cyprus Asbestos produced mainly chrysotile grades 3S and HSH. The company began developing new grades of chrysotile when sales of grades 3S and HSH declined. In 1985, full-scale production of chrysotile grades 4 through 7 was begun.[13] Approximately 40% of production is grade 4T, and 30% is grade 5R and 6D. Most of the asbestos produced is exported to Europe, the Middle East, the Far East, and India for asbestos cement products.

**U.S.S.R.**—Chrysotile asbestos production was estimated to be slightly greater than that of 1984.[14] Reconstruction and modernization of equipment at the Uralasbest complex was reported to have increased mine efficiency. In addition, the Baikal-Amor Mainline Railway was being developed to improve access to the Kiyembay complex in Siberia's South Muya mountain range.

Approximately 45% of the production was exported, mainly to centrally planned economy countries. In recent years, surplus fiber also has been marketed in market economy countries.

**United Kingdom.**—The Health and Safety Commission introduced new proposals to improve control of asbestos in the workplace.[15] These proposals were in response to a European Economic Community directive on worker protection and asbestos usage. The key provisions included assessment of the nature and degree of exposure and preventive measures to minimize exposure. Emphasis was placed on air monitoring, medical surveillance, and provisions for washing, changing, eating, and drinking.

**Table 9.—Asbestos: World production, by country[1]**

(Metric tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina | 1,280 | 1,218 | 1,240 | [e]1,250 | 1,200 |
| Australia | 45,494 | 18,587 | 3,723 | (3) | -- |
| Brazil (fiber) | [r]138,417 | 145,998 | 158,885 | 131,000 | 135,000 |
| Bulgaria | 400 | 600 | 700 | 500 | 600 |
| Canada (shipments) | 1,122,000 | 834,000 | 858,000 | 837,000 | 742,000 |
| China[e] | 106,000 | 110,000 | 160,000 | [r]135,000 | 140,000 |
| Colombia[e] | 5,400 | 5,400 | 5,400 | [4]9,982 | 10,000 |
| Cyprus | 24,440 | 18,952 | 17,288 | 7,429 | 6,000 |
| Egypt | 325 | 424 | 245 | [e]325 | 325 |
| Greece | 457 | 17,016 | 31,811 | 45,376 | 48,000 |
| India | 24,515 | 26,761 | 24,873 | 25,450 | 25,000 |
| Indonesia[e] | 5,000 | 25,000 | 25,000 | 25,000 | 25,000 |

See footnotes at end of table.

**Table 9.—Asbestos: World production, by country[1] —Continued**

(Metric tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Italy | 137,086 | 116,410 | 139,054 | 147,272 | 140,000 |
| Japan | 3,950 | 4,135 | [e]4,000 | [e]4,000 | 4,000 |
| Korea, Republic of | 14,084 | 15,933 | 12,506 | 8,062 | 10,000 |
| Mozambique | [r]1,425 | [r]852 | [e]800 | [e]800 | 800 |
| South Africa, Republic of | 235,943 | 211,860 | 221,111 | 167,389 | 165,000 |
| Swaziland | 35,264 | [r]30,145 | 26,287 | 25,832 | 26,000 |
| Taiwan | 2,317 | 2,392 | 2,819 | 1,355 | 1,500 |
| Turkey | 3,860 | 958 | 1,510 | 1,499 | 1,500 |
| U.S.S.R.[e] | 2,105,000 | 2,180,000 | 2,250,000 | 2,300,000 | 2,400,000 |
| United States (sold or used by producers) | 75,618 | 63,515 | 69,906 | 57,422 | [4]57,457 |
| Yugoslavia | 13,591 | 11,657 | 10,502 | 8,556 | [4]6,916 |
| Zimbabwe | 247,600 | 194,400 | 153,000 | 165,385 | 165,000 |
| Total | [r]4,349,466 | [r]4,036,213 | 4,178,660 | 4,105,884 | 4,111,298 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Table includes data available through Apr. 29, 1986.

[2]In addition to the countries listed, Afghanistan, Czechoslovakia, North Korea, and Romania also produce asbestos, but output is not officially reported, and available general information is inadequate for the formulation of reliable estimates of output levels.

[3]Revised to zero.

[4]Reported figure.

## TECHNOLOGY

Preliminary laboratory testing for the mutagenicity of surface-treated chrysotile indicated that it was less biologically reactive than untreated chrysotile.[16] The treated chrysotile, which is being developed by Société Nationale de l'Amiante of Quebec, was produced by exposing chrysotile to phosphorus oxychloride and phosphorus pentachloride vapors. Phosphorus compounds were chemically bonded to the chrysotile fiber surface when the gas reacted with the chrysotile. The lower mutagenicity was attributed to the phosphorus compound coating. If a safe form of modified chrysotile is developed, chrysotile could continue to be used commercially. Use of chrysotile rather than asbestos substitutes would be advantageous to industry because the engineering and physical properties of chrysotile are well known and existing technology could continue to be used. The use of substitute materials would require some modification to current industrial production processes and possibly require the development of new products. The long-term quality of products using substitute materials has not been documented, and long-term health effects also are unknown.

The concentrations of airborne asbestos in ambient environments were determined using transmission electron microscopy.[17] However, ambient asbestos levels determined by this technique varied by several orders of magnitude owing to the lack of standard reference materials (SRM). The National Bureau of Standards (NBS) in cooperation with EPA developed reference materials (RM) and SRM for use in testing, refining, and calibrating sample preparation and analysis procedures. These standards were prepared on polycarbonate filters and consist of chrysotile asbestos fibers mixed with NBS SRM 1648, an urban-air particulate matrix. The RM was typical of a general urban environment with low concentrations of ambient chrysotile. The SRM was representative of an ambient air sample collected near an asbestos source.

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[1]Physical scientist, Division of Industrial Minerals.

[2]Asbestos Information Association News and Notes. May 31, 1985, p. 1.

[3]Federal Register. Environmental Protection Agency. Asbestos Abatement Projects. V. 50, No. 134, July 12, 1985, pp. 28530-28540.

[4]———. Environmental Protection Agency. National Primary Drinking Water Regulations; Synthetic Organic Chemicals, Inorganic Chemicals and Microorganisms; Proposed Rule. V. 50, No. 219, Nov. 13, 1985, pp. 46880-46963.

[5]Environment Reporter, Special Analysis. Bur. of Nat. Affairs Inc., Washington, DC, Mar. 3, 1986, pp. 2050-2051.

[6]Asbestos Information Association News and Notes. Dec. 31, 1985, p. 1.

[7]Chemical & Engineering News. Asbestos Defendants Set Up Claims Center. V. 63, No. 25, June 24, 1985, p. 19.

[8]Industrial Minerals (London). Comment. No. 211, Apr. 1985, p. 7.

[9]Asbestos Information Association News and Notes. June 28, 1985, p. 1.

[10]Industrial Minerals (London). Company News and Mineral Notes. No. 216, Sept. 1985, p. 109.

[11]———. World of Minerals. No. 217, Oct. 1985, pp. 11-12.

[12]———. Company News and Mineral Notes. No. 215, Aug. 1985, p. 63.

[13]Griffiths, J. Asbestos. Ind. Miner. (London), No. 223, Apr. 1986, pp. 21-37.

[14]Work cited in footnote 13.

[15]Industrial Minerals (London). Company News and Mineral Notes. No. 208, Jan. 1985, p. 70.

[16]Langer, A. N., R. P. Nolan, and I. Weisman. Chrysotile and Chrysophosphate. Pres. at 15th Annu. Meeting, Asbestos Information Assoc., Sept. 17-18, 1985, Arlington, VA; available from A. N. Langer, Environmental Sciences Laboratory, Mount Sinai School of Medicine of the City University of New York, New York, NY.

[17]Small, J., E. Steel, and P. Sheridan. Analytical Standards for the Analysis of Chrysotile Asbestos in Ambient Environments. Anal. Chem., v. 57, No. 1, Jan. 1985, pp. 204-208.

# Barite

## By Sarkis G. Ampian[1]

Domestic production of barite, after increasing in 1984, resumed the downward trend started in 1982 by decreasing 5% to 739,000 short tons valued at $21 million. Production from Nevada, the leading producer, decreased 4% to 590,000 tons. Production from Georgia and Missouri, the second and third leading States, respectively, decreased. Imports for consumption of crude barite rose 19% to 2.1 million tons, and ground barite imports increased nearly 60% from 45,024 tons to 71,024 tons valued at $4.7 million. Imports of barite for the fourth straight year led domestic production, and the 2.1-million-ton import figure for 1985 was only 200,000 tons below the record high imported during 1982. Ground barite imports, except for the drilling boom years of the late 1970's and early 1980's, were negligible. The principal use for barite, as a weighting agent in oil- and gas-well-drilling fluids (muds), accounted for 93% of U.S. consumption. Chemicals, glass, and filler and/or extender uses accounted for the remaining 7%.

Demand for barite, after increasing in 1984, returned to the downward slide that began in 1982 owing to a decrease in drilling activity, prompted by oil oversupplies. However, this decrease was accompanied by the return to drilling deeper wells that consume more barite. U.S. mine production continued, although still depressed, spurred on by regional sales and lower rail rates, which increased the competitiveness of domestic ores in the gulf coast and midcontinent areas. Barite grinding capacity, despite numerous closures, mergers, and acquisitions, continued in a position to meet present and future requirements.

**Domestic Data Coverage.**—Domestic production data for barite are developed by the Bureau of Mines from one voluntary survey of U.S. operations. Of the 108 operations to which a survey request was sent, all responded, representing 100% of the total crushed and ground production sold or used shown in table 1.

**Table 1.—Salient barite and barium chemical statistics**

(Thousand short tons and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Barite, primary: | | | | | |
| Sold or used by producers | 2,849 | 1,845 | 754 | 775 | 739 |
| Value | $102,439 | $69,522 | $29,208 | $25,445 | $21,501 |
| Exports | 62 | 49 | 23 | 1 | 6 |
| Value | $9,947 | $6,510 | $3,514 | $574 | $692 |
| Imports for consumption (crude) | 1,932 | 2,320 | 1,396 | 1,731 | 2,056 |
| Consumption (apparent)[1] | 4,719 | 4,116 | 2,127 | 2,505 | 2,789 |
| Crushed and ground (sold or used by processors)[2] | 4,716 | 4,088 | 2,745 | 2,883 | 2,184 |
| Value | $406,255 | $322,700 | $194,380 | $220,806 | $154,463 |
| Barium chemicals (sold or used by processors) | 34 | 25 | 22 | 26 | 24 |
| Value | $20,670 | $18,720 | $16,860 | $17,105 | $16,036 |
| World: Production | [r]9,057 | [r]8,002 | 5,982 | [p]6,352 | [e]6,671 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Sold or used plus imports minus exports.

[2]Includes imports.

## DOMESTIC PRODUCTION

The term "primary barite" denotes the first marketable product and includes crude run-of-mine barite, flotation concentrates, and material concentrated by other beneficiated processes such as washing, jigging, or magnetic separation. Run-of-mine barite, the lowest cost primary barite, sold or used by producers represented 59% of total production compared with 64% in 1984; flotation concentrates was 8% of total 1985 production; and the balance was other beneficiated material.

Reported primary production decreased 5%. Nevada and Georgia remained the two leading barite producing States. Other producing States, in descending order, were Missouri, Montana, Tennessee, Washington, and Illinois. Barite was produced as a coproduct of fluorspar mining and milling in Illinois, and in Washington, production was limited to stockpile shipments; in all other States, barite is the primary product.

The leading domestic barite producers were Dresser Minerals Div., Dresser Industries Inc.; IMCO Services Div., Halliburton Co.; and NL BAROID/NL Industries Inc., all with mines in Missouri and Nevada; and Milchem Inc., with mines in Nevada. Another producer in Nevada was FMC Corp., and in Missouri, DeSoto Mining Co. and General Barite Co.

The domestic barite industry experienced a downturn during the year primarily owing to a decrease in drilling activity. This downturn, except for a slight upturn in 1984, returns to the trend of declining barite production rates that have been prevalent since 1981, the record-high production year (2.8 million tons). Production data also revealed that, despite a downturn in drilling activity, lower rail rates to the gulf coast and midcontinent areas based on unit trains and guaranteed tonnage contracts enabled modest domestic mining campaigns. Nevertheless, the persistent oil glut and lower energy consumption rates exacerbated at yearend by Mideast overproduction continued to thwart an upturn in oil- and gas-well-drilling activity. Other factors depressing the domestic marketplace were the continued low oil prices that discouraged exploration drilling activity and the world barite oversupply and lower ocean freight rates, in part owing to lower bunker fuel costs and excess bottoms. These factors combined to make foreign ores more attractively priced than domestic barite. In addition, the shrinking domestic market, the world's largest, has turned a soft market situation into a buyer's market. The competitiveness of the domestic industry, both for producers and grinders alike, continued to be threatened by imports of ground barite into an already depressed marketplace, which could further soften foreign barite prices.

A majority of the mining and grinding facilities still operational continued to be either suspended or on minimal production schedules. Most changes to mining, milling, and/or grinding capacity were largely modernizations and flowsheet changes to reduce production costs to remain competitive in the current soft market situation. Many capital-intensive projects, both ongoing and planned, have been deferred indefinitely. In some circumstances, companies closed their grinding plants and were obtaining specification-grade drilling mud barite from custom grinders.

In mergers, acquisitions, and closures, Milchem, a subsidiary of Baker International Corp., and Eisenman Chemical Co., a subsidiary of Newpark Resources Inc., formed a partnership, Milpark, to run their merged mining and grinding facilities. Eisenman's Corpus Christi, TX, mill and Milchem's Argenta Mine, and plants in New Orleans, LA, Galveston, TX, and Oklahoma, were operational.

The Environmental Protection Agency issued a final general National Pollutant Discharge Elimination System permit for oil and gas stratigraphic and exploration tests in the Outer Continental Shelf of Alaska, excluding development or production operations, in Federal water.[2] A similar draft permit factsheet was issued for oil and gas operations in portions of the Gulf of Mexico.[3]

Table 2.—U.S. primary barite sold or used by producers, by State

| State | Number of operations | Run of mine |  | Flotation concentrates |  | Beneficiated material[1] |  | Total |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Quantity (thousand short tons) | Value (thousands) | Quantity (thousand short tons) | Value (thousands) | Quantity (thousand short tons) | Value (thousands) | Quantity (thousand short tons) | Value (thousands) |
| 1984: |  |  |  |  |  |  |  |  |  |
| Georgia | 2 | -- | -- | W | W | W | W | W | W |
| Illinois | 1 | -- | -- | W | W | -- | -- | W | W |
| Missouri | 3 | W | W | -- | -- | W | W | W | W |
| Montana | 1 | W | W | -- | -- | W | W | W | W |
| Nevada | 10 | 449 | $10,527 | -- | -- | 166 | $4,397 | 615 | $14,924 |
| Tennessee | 1 | W | W | -- | -- | -- | -- | W | W |
| Washington | 1 | -- | -- | W | W | -- | -- | W | W |
| Total | 19 | 499 | 12,298 | 60 | $4,146 | 216 | 9,000 | 775 | [2]25,445 |
| 1985: |  |  |  |  |  |  |  |  |  |
| Georgia | 2 | -- | -- | W | W | W | W | W | W |
| Illinois | 1 | -- | -- | W | W | -- | -- | W | W |
| Missouri | 3 | 26 | 896 | -- | -- | 21 | 1,895 | 47 | 2,791 |
| Montana | 1 | W | W | -- | -- | -- | -- | W | W |
| Nevada | 9 | 389 | 7,485 | -- | -- | 201 | 3,419 | 590 | 10,904 |
| Tennessee | 1 | W | W | -- | -- | -- | -- | W | W |
| Washington | 1 | -- | -- | W | W | -- | -- | W | W |
| Total | 18 | 436 | 9,441 | 58 | 4,099 | 246 | 7,961 | [2]739 | 21,501 |

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Includes some flotation concentrates.

[2] Data do not add to total shown because of independent rounding.

## CONSUMPTION AND USES

Consumption of crushed and ground barite decreased about 24% from 2.9 million tons in 1984 to 2.2 million tons in 1985. This downturn, after an increase in 1984, reinstates the downtrend in barite consumption that has occurred since 1981, when the record high of 4.7 million tons of crushed and ground barite was established. This decrease indicated a downturn in barite required for oil-well drilling, which accounted for 93% of total sales. The oil- and gas-well-drilling industry completed over 52,000 wells and drilled over 243 million feet of hole.[4] The figures indicated a decrease from that of 1984 in the number of wells and feet drilled of 36% and 30%, respectively.

Total well footage drilled exceeded 10 million feet in five States: Texas, 95.0 million feet; Oklahoma, 29.8 million feet; Louisiana, 26.6 million feet; Kansas, 15.3 million feet; and Ohio, 10.5 million feet. Generally, the deeper a hole is drilled, the more barite is used per foot of drilling. Among the five leading States, Louisiana had the highest well depth, over 5,500 feet, and Kansas, the lowest, had an average depth of about 3,800 feet. Wyoming, absent from the top States this year in well footage drilled, again had the highest average well depth, nearly 7,500 feet. The U.S. average increased nearly 500 feet to 4,700 feet. The main reason that barite consumption decreased was because of the 64% reduction in the number of wells drilled. This decrease, however, was offset by an increase of barite per foot of drilling, which rose to 16.8 pounds per foot of drilling compared with 15.5 pounds per foot in 1984.

The increase was due to deeper drilling rigs that require more barite. Another benchmark of drilling activity, the Hughes Tool Co. rig count, showed the average number of operating domestic rigs decreased by over 18% to 1,980 rigs.[5] The decrease in rigs reestablished a downward trend that, except for 1984, saw the number of rigs fall from the 1981 record high of 3,969 rigs to 2,232 rigs in 1983. The 1986 average rig count of 1,980 is the first time since 1976 (1,658 rigs) that the count was below 2,000. The estimated rig count during the year ranged from a low of 1,858 to a high of 2,452.

## Table 3.—Crushed and ground barite[1] sold or used by processors in the United States, by State

| State | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Number of plants | Quantity (thousand short tons) | Value (thousands) | Number of plants | Quantity (thousand short tons) | Value (thousands) |
| Louisiana | 13 | 1,315 | $109,413 | 10 | 937 | $60,702 |
| Missouri | 2 | W | W | 3 | 15 | 1,529 |
| Nevada | 9 | 478 | 15,691 | 4 | 274 | 13,426 |
| Oklahoma | 5 | 91 | 6,737 | 4 | 79 | 6,206 |
| Texas | 14 | 783 | 63,186 | 13 | 700 | 49,163 |
| Utah | 4 | 55 | 3,976 | 4 | 35 | 2,493 |
| Other[2] | 11 | 161 | 21,803 | 9 | 144 | 20,944 |
| Total | 58 | 2,883 | 220,806 | 47 | 2,184 | 154,463 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes imports.

[2] Includes Arkansas, California, Georgia, Illinois, Montana, New York, and Washington (1984).

## Table 4.—Crushed and ground barite[1] sold or used by processors in the United States, by use

(Thousand short tons and thousand dollars)

| Use | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Barium chemicals, filler and/or extender, glass | 188 | 23,783 | 142 | 21,504 |
| Well drilling | 2,695 | 197,023 | 2,042 | 132,959 |
| Total | 2,883 | 220,806 | 2,184 | 154,463 |

[1] Includes imports.

## Table 5.—U.S. barium chemicals[1] produced and sold or used by processors

| Barium chemical | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Plants[2] | Production (short tons) | Sold or used by processors | | Plants[2] | Production (short tons) | Sold or used by processors | |
| | | | Quantity (short tons) | Value (thousands) | | | Quantity (short tons) | Value (thousands) |
| Barium carbonate | 2 | W | W | W | 2 | W | W | W |
| Barium chloride | 2 | W | W | W | 2 | W | W | W |
| Black ash | 1 | W | W | W | 1 | W | W | W |
| Blanc fixe | 1 | W | W | W | 1 | W | W | W |
| Other | 2 | 27,364 | 26,249 | $17,105 | 2 | 24,057 | 23,811 | $16,036 |
| Total | 3 | 27,364 | 26,249 | 17,105 | 3 | 24,057 | 23,811 | 16,036 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Only data reported by barium chemical plants that consume barite are included. Partially estimated.

[2] A plant producing more than one product is counted only once.

Table 6.—U.S. hydrocarbon well drilling and barite consumption

| Year | Barite used for well drilling (thousand short tons) | Wells drilled (thousands)[1] | | | | Successful wells (percent) | Average depth per well (feet) | Average barite per well (short tons) |
|---|---|---|---|---|---|---|---|---|
| | | Oil | Gas | Dry holes | Total | | | |
| 1965 | 987 | 18.07 | 4.48 | 16.23 | 38.78 | 58.1 | 4,510 | 25.45 |
| 1966 | 1,022 | 16.78 | 4.38 | 15.23 | 36.39 | 58.1 | 4,478 | 28.08 |
| 1967 | 965 | 15.33 | 3.66 | 13.23 | 32.22 | 58.9 | 4,385 | 29.95 |
| 1968 | 1,006 | 14.33 | 3.46 | 12.81 | 30.60 | 58.1 | 4,738 | 32.88 |
| 1969 | 1,235 | 14.37 | 4.08 | 13.74 | 32.19 | 57.3 | 4,881 | 38.37 |
| 1970 | 1,119 | 13.02 | 3.84 | 11.26 | 28.12 | 60.0 | 4,952 | 39.79 |
| 1971 | 1,044 | 11.86 | 3.83 | 10.16 | 25.85 | 60.7 | 4,806 | 40.39 |
| 1972 | 1,183 | 11.31 | 4.93 | 11.06 | 27.30 | 59.5 | 4,932 | 43.33 |
| 1973 | 1,326 | 9.90 | 6.39 | 10.31 | 26.60 | 61.2 | 5,129 | 49.85 |
| 1974 | 1,440 | 12.78 | 7.24 | 11.67 | 31.69 | 63.2 | 4,750 | 45.44 |
| 1975 | 1,638 | 16.41 | 7.58 | 13.25 | 37.24 | 64.4 | 4,685 | 43.98 |
| 1976 | 1,986 | 17.06 | 9.09 | 13.62 | 39.77 | 65.7 | 4,571 | 49.94 |
| 1977 | 2,372 | 18.91 | 11.38 | 14.69 | 44.98 | 67.3 | 4,687 | 52.73 |
| 1978 | 2,632 | 17.76 | 12.93 | 16.25 | 46.94 | 65.4 | 4,829 | 56.07 |
| 1979 | 2,967 | 19.38 | 14.68 | 15.75 | 49.81 | 68.4 | 4,791 | 59.57 |
| 1980 | 3,385 | 26.99 | 15.74 | 18.09 | 60.82 | 70.3 | 4,675 | 55.66 |
| 1981 | 4,526 | 37.67 | 17.89 | 22.97 | 78.53 | 70.8 | 4,602 | 57.63 |
| 1982 | 4,048 | 40.30 | 18.95 | 26.55 | 85.80 | 69.1 | 4,616 | 47.18 |
| 1983 | 2,648 | 37.21 | 15.63 | 23.49 | 76.33 | 69.2 | 4,268 | 34.69 |
| 1984 | 2,695 | 41.10 | 15.71 | 25.23 | 82.04 | 69.5 | 4,246 | 32.85 |
| 1985 | 2,042 | 26.24 | 10.15 | 15.97 | 52.36 | 69.5 | 4,658 | 39.00 |

[1] Includes exploratory and development wells; excludes service wells, stratigraphic tests, and core tests.

Source: American Petroleum Institute.

## PRICES

Price quotations in trade publications for barite remained unchanged. These prices may serve as a general guide but do not reflect actual transactions.

The reported average value per ton of domestic barite, based on actual sales, decreased nearly 13% f.o.b. plant. The average reported value per ton of ground drilling-mud-grade barite from Louisiana and Texas was $67.28; the average value of that from California, Nevada, and Utah was $62.50 per ton. The value of the Louisiana and Texas ground material, in direct response to both foreign competition and soft market conditions, declined 18%. Material from the other major grinding States remained relatively unchanged. The average customs value of barite exported to Canada was about $275 per ton; the customs value of material exported to Mexico and Latin America was about $110 per ton.

Table 7.—Barite price quotations

| Item | Price per short ton[1] | |
|---|---|---|
| | 1984 | 1985 |
| Barite:[2] | | |
| Chemical, filler, glass grades, f.o.b. shipping point, carlots: | | |
| Handpicked, 95% $BaSO_4$, not over 1% Fe | $90.00 | $90.00 |
| Magnetic or flotation, 96% to 98% $BaSO_4$, not over 0.5% Fe | 106.00 | 106.00 |
| Water-ground, 95% $BaSO_4$, 325 mesh, 50-pound bags | $80.00-165.00 | $80.00-165.00 |
| Drilling-mud-grade: | | |
| Dry-ground, 83% to 93% $BaSO_4$, 3% to 12% Fe, specific gravity 4.20 to 4.30, f.o.b. shipping point, carlots | 80.00-115.00 | 80.00-115.00 |
| Crude, imported, specific gravity 4.20 to 4.30, f.o.b. shipping point | 55.00- 75.00 | 55.00- 75.00 |
| Barium chemicals:[3] | | |
| Barium carbonate: | | |
| Precipitated, bulk, carlots, freight equalized (per pound) | .24 | .25 |
| Electronics-grade, bags | 510.00 | 510.00 |
| Barium chloride: | | |
| Technical crystals, bags, carlots, works | 450.00 | 450.00 |
| Anhydrous, bags, carlots, same basis | 565.00 | 565.00 |
| Barium hydrate: Mono, 55-pound bags, carlots, delivered (100 pounds) | 46.00 | 46.00 |

See footnotes at end of table.

Table 7.—Barite price quotations —Continued

| Item | Price per short ton[1] | |
|---|---|---|
| | 1984 | 1985 |
| Barium chemicals[3] —Continued | | |
| Barium sulfate: | | |
| Blanc fixe, technical-grade, bags, carlots | 400.00 | 400.00 |
| U.S.P., X-ray diagnosis-grade, powder, 25-kilogram bags, 10,000-kilogram lots (per pound) | .59 | .59 |
| Barium sulfide (black ash), drums, carlots, works | 460.00 | 460.00 |

[1] Unless otherwise specified.

[2] Engineering and Mining Journal. V. 185, No. 12, Dec. 1984, p. 27; and v. 186, No. 12, Dec. 1985, p. 11.

[3] Chemical Marketing Reporter. V. 226, No. 27, Dec. 31, 1984, p. 21; and v. 228, No. 25, Dec. 16, 1985, p. 41.

## FOREIGN TRADE

Exports of natural barium sulfate or barite increased fourfold from about 1,500 tons to nearly 6,000 tons. This represented an increase in exports after 5 consecutive years of decline from the record high of 1979 when 109,000 tons was exported. The 1984 and 1985 ground barite exports are the smallest since 1969, when barite export statistics were first listed in the "Minerals Yearbook." Export and import data provided by the Bureau of the Census do not indicate the grades of barite traded; however, based on the value of individual shipments, an estimated 80% was ground drilling-mud grade, and an estimated 20% was chemical, filler, or glass grade. Crude barite was not exported in 1985. Canada and Mexico, traditionally either first or second among export recipients, were replaced by Liberia, the Barbados, and Mozambique, in decreasing order, as the leading buyers of U.S. ground barite and accounted for 64% of the total exports. Canada and Mexico received about 15% of the total. Exports to Mexico, a major oil producing country, declined to only 5 tons from a high of 18,000 tons in 1983. Both Canada and Mexico continued to rely more on domestic production. The strong U.S. dollar, which weakened at yearend, along with low exploration levels continued to have an adverse effect on barite exports.

Imports of crude barite increased 19% from 1.73 million tons to 2.06 million tons. The 1985 barite import figure was still 11% below the record high of 2.32 million tons set in 1982. The average unit c.i.f.[6] value of this material dropped 8% to $38.04 per ton, indicating that prices of foreign ores continued to decline in response to oversupply and lower ocean shipping rates. Domestic producers and consumers, faced with high rail rates from domestic drilling-quality barite mines in Nevada to gulf coast area grinding plants, continued to take advantage of the lower priced foreign ores to meet their demands in this highly competitive gulf coast area. Average value per ton of material shipped from the principal source countries was Mexico, $42.84; India, $38.66; China, $38,47; Thailand, $37.93; Morocco, $37.27; Indonesia, $36.86; Peru, $36.50; Chile, $27.81; and Ireland, $26.60. The costlier, high-quality barite, generally material with a specific gravity greater than 4.2, is usually blended with lower grade ore, foreign or domestic, during grinding to meet American Petroleum Institute specifications for 4.2 drilling-mud-grade barite. Imports of ground barite increased nearly 58% to over 71,000 tons from about 45,000 tons in 1984; of this, China and Morocco supplied 67% and 24%, respectively. Ground barite imports up to those of 1983 had been limited to premium-quality pharmaceutical grade from Belgium-Luxembourg, Canada, France, the Federal Republic of Germany, and the Netherlands, unavailable domestically and averaging $300 to $600 per ton. The average c.i.f. value of the Chinese and Moroccan imports, $53.22 and $73.30, respectively, suggests that this barite is probably drilling-grade material. The last significant imports of mud-grade barite, excluding that of 1984, occurred during the drilling boom years of the late 1970's and early 1980's when imports, mainly from Morocco, Mexico, Singapore, and China, in decreasing order, averaged under 10,000 tons per year. Continued imports of ground drilling-grade barite, in an already soft market situation, will probably result in the closure of some grinding plants and adversely affect the few domestic mines that still supply ore for blending. The value of imports from Thailand, about $115 per ton, indicates that this ground material was probably destined for domestic filler and/or extender markets that are usually supplied by U.S. producers. Crude barite, for the most part, entered through customs districts near most drilling-mud markets along the gulf coast for delivery to grinding plants in the area. The import distribution by customs districts in 1985 (1984) was New Orleans, LA, 58% (53%); Houston, TX, 38% (31%); Laredo, TX (Port of Brownsville, TX), 4% (8%); and Port Arthur, TX (includes Port of Lake Charles, LA), 0% (8%).

Imports of barium chemicals decreased 7% to about 33,000 tons valued at over $20 million. Barium carbonate, the predominant chemical imported, declined nearly 14% to nearly 12,500 tons. The Federal Republic of Germany, China, Italy, Brazil, Canada, and Japan, in descending order, were the major suppliers.

### Table 8.—U.S. exports of natural barium sulfate, by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Argentina | 25 | $9 | 59 | $43 |
| Barbados | 259 | 30 | 1,266 | 149 |
| Canada | 707 | 254 | 897 | 244 |
| Japan | 62 | 20 | 21 | 8 |
| Liberia | -- | -- | 1,485 | 16 |
| Mexico | 87 | 193 | 5 | 1 |
| Mozambique | -- | -- | 1,018 | 82 |
| Paraguay | -- | -- | 762 | 81 |
| Philippines | 36 | 13 | 14 | 3 |
| Venezuela | 39 | 21 | 50 | 24 |
| Other | 235 | 34 | 301 | 42 |
| Total[1] | 1,449 | 574 | 5,876 | 692 |

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

### Table 9.—U.S. imports for consumption of barite, by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (short tons) | Value[1] (thousands) | Quantity (short tons) | Value[1] (thousands) |
| Crude barite: | | | | |
| Chile | 87,202 | $3,136 | 72,219 | $2,008 |
| China | 905,158 | 40,038 | 890,659 | 34,265 |
| India | 133,785 | 4,997 | 443,406 | 17,142 |
| Indonesia | -- | -- | 33,013 | 1,217 |
| Ireland | 39,683 | 1,509 | 19,499 | 519 |
| Mexico | 59,446 | 1,275 | 35,533 | 1,522 |
| Morocco | 335,375 | 13,582 | 319,207 | 11,897 |
| Peru | 64,006 | 2,618 | 28,991 | 1,058 |
| Switzerland | -- | -- | 80,919 | 3,410 |
| Thailand | 64,753 | 2,618 | 115,316 | 4,374 |
| Other | 41,552 | 1,937 | 17,162 | 803 |
| Total[2] | 1,730,960 | 71,708 | 2,055,924 | 78,216 |
| Ground barite: | | | | |
| Belgium-Luxembourg | 103 | 41 | 20 | 6 |
| Canada | 1,565 | 374 | 3,539 | 499 |
| China | 31,382 | 1,691 | 47,779 | 2,543 |
| France | 80 | 24 | 20 | 5 |
| Germany, Federal Republic of | 324 | 92 | 353 | 106 |
| Mexico | 1 | ([3]) | -- | -- |
| Morocco | 11,112 | 887 | 17,107 | 1,254 |
| Netherlands | 368 | 115 | 146 | 46 |
| Thailand | 67 | 10 | 2,050 | 234 |
| Turkey | 22 | 3 | -- | -- |
| Other | -- | -- | 10 | 4 |
| Total | 45,024 | 3,237 | 71,024 | 4,697 |

[1] C.i.f. value.
[2] Data may not add to totals shown because of independent rounding.
[3] Less than 1/2 unit.

Source: Bureau of the Census.

### Table 10.—U.S. imports for consumption of barium chemicals

| Year | Lithopone | | Blanc fixe (precipitated barium sulfate) | | Barium chloride | | Barium hydroxide | |
|---|---|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1981 | NA | NA | 8,402 | $5,369 | 3,601 | $1,170 | 3,663 | $2,451 |
| 1982 | NA | NA | 8,135 | 5,580 | 2,930 | 878 | 3,570 | 2,758 |
| 1983 | NA | NA | 9,087 | 5,911 | 3,402 | 1,016 | 4,799 | 3,751 |
| 1984 | NA | NA | 9,302 | 6,381 | 3,680 | 1,576 | 5,452 | 3,973 |
| 1985 | NA | NA | 8,971 | 6,295 | 2,839 | 1,125 | 5,708 | 3,959 |

| Year | Barium nitrate | | Barium carbonate, precipitated | | Other barium compounds | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1981 | 270 | $87 | 5,709 | $2,323 | 664 | $538 |
| 1982 | 682 | 263 | 7,787 | 3,055 | 753 | 629 |
| 1983 | 777 | 275 | 8,821 | 3,884 | 946 | 1,256 |
| 1984 | 1,278 | 478 | 14,476 | 7,269 | 1,020 | 847 |
| 1985 | 1,339 | 643 | 12,457 | 5,400 | 1,593 | 2,556 |

NA Not available.

Source: Bureau of the Census.

### Table 11.—U.S. imports for consumption of crude, unground, and crushed or ground witherite[1]

| Year | Crude, unground | | Crushed or ground | |
|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1981 | 7 | $2 | 92 | $85 |
| 1982 | 292 | 82 | 41 | 44 |
| 1983 | 1 | 4 | 49 | 12 |
| 1984 | 41 | 24 | 185 | 129 |
| 1985 | 1 | 6 | 141 | 68 |

[1] Barium carbonate.

Source: Bureau of the Census.

## WORLD REVIEW

Estimated world production of barite increased slightly to 6.7 million tons. The United States produced 11% of the world total and imported 31% of the world output.

**Canada.**—The Newfoundland and Labrador Department of Mines was involved in a number of industrial minerals projects including a major study of their barite resources.[7] The projects were designed chiefly to exploit the areas' mineral deposits.

**China.**—The Ministry of Geology and Mineral Resources reported the discovery of a barite deposit containing about 400 million tons of recoverable ore.[8] The ore body between the Hunan, Guizhou, and Guangxi Provinces is close to the surface and easily minable. The Government was pressing to develop new barite mines to ensure its market shares in the drilling-mud, chemical, and filler-extender industries.[9]

**Gabon.**—The Government was seeking assistance in exploiting its Bourekiki barite deposit, which has stated ore reserves in excess of 1 million tons.[10] Initial plans called for a $15 million mining operation, with the barite being marketed mostly in the neighboring countries of Angola and the Congo.

**Greece.**—The downturn in worldwide oil and gas drilling activities forced Silver and Barytes Ores Mining Co. to operate its Kavos and Pikridou Mines on the Island of Milos on an intermittent basis.[11] The facility, capable of producing 6,000 tons of 3.9 specific gravity filler-grade material, completed installation of a 12,000-ton-per-year flotation plant to upgrade the ore to meet drilling-mud specifications.

**India.**—Mineral and Metal Trading Corp. started on its long-range plans of diversifying and expanding along the lines of some of the large Japanese trading companies.[12] Future activities were to include mining, mine financing, trading, and distribution aimed at increasing its turnover by 1990. One announced mining plan was a joint venture with Andhra Pradesh Mineral and Development Corp. (APMDC) to develop a barite operation in southern India.

APMDC, with nearly 80 million tons of barite reserves (one-third of the country's total), reportedly contributed over 98% of India's total barite production.[13] In addition to Andhra Pradesh, the other producing States, in descending order, are Rajasthan, Madhya Pradesh, Maharashtra, and Bihar.

**Indonesia.**—Large deposits of high-quality barite were discovered on Lembata Island in East Nusa Tenggara.[14] The find was made by P.T. Bariod Indonesia, a joint venture between NL BAROID/NL Industries and P.T. Indokar. Indonesia planned to discontinue barite imports from Thailand when the new mines and mill complex come on-stream.

**Malaysia.**—The Government's Malaysia Mining Corp. announced a feasibility study for its newly outlined barite deposit, containing upwards of 500,000 tons of reserves, at Sungei Pedah.

**Mexico.**—Church and Dwight Co. Inc., Piscataway, NJ, purchased 49% interest in Sales y Óxides, a Monterrey-based producer of barium and strontium carbonates.[15] Production capacity increases were planned for the strontium chemical stream.

**Oman.**—IMCO Services, a division of Halliburton, placed its grinding plant on-stream early in the year.[16]

**Pakistan.**—The Geological Survey's extensive exploratory and evaluation work over the last 4 years located several viable industrial mineral deposits.[17] One area of note is the barite associated with lead-zinc mineralization in the Khuzdar District.

**Tunisia.**—Expansion plans at the Zriba fluorspar operations, scheduled for completion in 1986, called for increasing byproduct barite production to about 40,000 tons per year.

**Turkey.**—Barit Maden Turk AS, a major barite producer and grinder, trebled its grinding capacity by acquiring Matosan Ltd.'s facilities.[18] Barit's grinding capacity will be increased to nearly 300,000 tons per year after new equipment is installed at its Bahce, Adana plant, about 50 miles from the Port of Iskenderun on the Mediterranean coast. Barit produces drilling-mud-grade barite from its mines in Marash, Adana, Sivas, and Kayseri Districts.

The State mining company, Etibank, was looking for foreign partners to upgrade its 100,000-ton-per-year open pit mine at Beysehir and the associated grinding and bagging facilities at Antalya.[19] The foreign partner was also expected to help in establishing new overseas markets.

**United Kingdom.**—Minworth Metals Ltd. began exploratory work and opencast mining operations for exploiting the larger and thicker barite veins found at Cumberhead in the Clydesdale District of southern Scotland.[20] The entire complex is planned to cover approximately 3 hectares of ground divided between three separate mines within 1 mile of each other. Minworth was also planning to build a 35,000-ton-per-year washing and heavy-media separation plant at Carluke, about 20 miles to the east of Cumberland, for the production of oil well drilling-grade material.

**Venezuela.**—The Ministry of Energy and Mines' preliminary findings from a number of mineral-related projects conducted during the year revealed a large deposit of drilling-mud-quality barite in the Northwestern Region.[21] Venezuela, a large oil producing country, currently imports about 100,000 tons of barite annually for its oil and gas exploration activities.

**Yugoslavia.**—New deposits of barite, with reserves estimated at 2 million tons, were found on Mount Bobija near Ljubovija in Serbia.[22] Although the Government already produces about 350,000 tons per year of barite, mostly for export, plans were under way to increase the concentrator's capacity an additional 35,000 tons annually.

### Table 12.—Barite: World production, by country[1]

(Thousand short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Afghanistan[3] | 1 | 2 | [e]2 | [r] [e]2 | 2 |
| Algeria | 98 | 112 | [e]120 | 97 | 100 |
| Argentina | 54 | 40 | 67 | 49 | 55 |
| Australia | 45 | 31 | 13 | 22 | 22 |
| Belgium[e] | 44 | 44 | 44 | [r]43 | 44 |
| Bolivia | 2 | 1 | 1 | 1 | 2 |
| Brazil | 128 | [r]155 | 140 | 158 | 160 |
| Burma[4] | 8 | 18 | 11 | [e]12 | 12 |
| Canada | 95 | 31 | 50 | 52 | 50 |
| Chile | 286 | 322 | 126 | 24 | 24 |
| China[e] | 880 | 990 | 1,100 | 1,100 | 1,100 |
| Colombia | [r]3 | 4 | 4 | 4 | 4 |
| Czechoslovakia[e] | 67 | 67 | 67 | [r]66 | 66 |
| Egypt | 2 | 3 | 4 | [e]4 | 4 |
| Finland | -- | -- | 4 | 10 | 10 |
| France | 210 | [r]158 | 168 | 163 | 165 |
| German Democratic Republic[e] | 39 | 39 | 39 | [r]39 | 37 |
| Germany, Federal Republic of | 182 | 183 | 181 | 184 | 187 |
| Greece[5] | 52 | [r]43 | 33 | 3 | 19 |
| Guatemala | 6 | 2 | [e]([6]) | ([6]) | ([6]) |
| India | 390 | 359 | 356 | 463 | 670 |
| Iran[e] | 83 | 88 | 94 | 100 | 100 |
| Ireland | 302 | [r]293 | 220 | 243 | 243 |
| Italy | 195 | 198 | 153 | 118 | 110 |
| Japan | 62 | 66 | 77 | 73 | [7]85 |
| Kenya | [e]7 | -- | ([6]) | ([6]) | ([6]) |
| Korea, North[e] | 110 | -- | -- | -- | -- |
| Korea, Republic of | -- | -- | 1 | 3 | 2 |
| Malaysia | 21 | 28 | 24 | 26 | 45 |
| Mexico | 350 | 401 | 394 | 470 | 540 |
| Morocco | 513 | [r]565 | 318 | 469 | 468 |
| Pakistan | [r]30 | [r]24 | 29 | 35 | 40 |
| Peru | 451 | 413 | [e]180 | [e]180 | 180 |
| Philippines | 2 | 10 | 1 | ([8]) | -- |
| Poland | 94 | 100 | 89 | 89 | 88 |
| Portugal | 1 | 1 | 1 | [e]([6]) | ([6]) |
| Romania[e] | 87 | 86 | 86 | 80 | 80 |
| South Africa, Republic of | [r]2 | 4 | 7 | 5 | [7]3 |
| Spain | 58 | 55 | 58 | 76 | 70 |
| Thailand | 338 | 365 | 207 | 193 | 190 |
| Tunisia | 27 | 34 | 22 | 13 | 22 |
| Turkey | 205 | [r]127 | 87 | 218 | 220 |
| U.S.S.R.[e] | 560 | 570 | 570 | [r]580 | 595 |
| United Kingdom | 69 | 89 | 40 | 69 | 77 |
| United States[9] | 2,849 | 1,845 | 754 | 775 | [7]739 |
| Yugoslavia | 49 | 35 | 39 | [e]40 | 40 |
| Zimbabwe | -- | 1 | 1 | 1 | 1 |
| Total | [r]9,057 | [r]8,002 | 5,982 | 6,352 | 6,671 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through June 17, 1986.

[2] In addition to the countries listed, Bulgaria also produces barite, but available information was inadequate to make reliable estimates of output levels.

[3] Year beginning Mar. 21 of that stated.

[4] Data are for fiscal years beginning Apr. 1 of that stated.

[5] Barite concentrates.

[6] Less than 1/2 unit.

[7] Reported figure.

[8] Revised to zero.

[9] Sold or used by producers.

## TECHNOLOGY

A short survey highlighting the qualities of Turkish barite deposits, including data on reserves, resources geology, mining and production methods, and recent production statistics, was published.[23] The paper features nonograms and graphs showing the relationship between barium sulfate ($BaSO_4$) content and density and its subsequent applicability in glass and chemicals manufacturing and its use in drilling muds. A comprehensive paper featuring barite was published in a treatise on the industrial minerals of the Federal Republic of Germany.[24] The article examines barite geology, mining and production methods, reserve estimates, and the individual companies involved in the nondrilling mud markets. High-quality West German barites have been traditionally used in barium chemicals, lithopone, and to a lesser degree in the filler and extender areas of paint, rubber, and plastics. Similar, but less vigorous studies, were released on the mineral industries of Greece,[25] Spain,[26] and California.[27] The Greek article stressed barite mining and processing flowsheets, while the Spanish work, in addition, detailed the geology of its deposits. The California study detailed its run-of-mine production of high-grade 4.4 specific gravity barite and blending schemes, using selected low-grade Nevada ore, to meet drilling mud specifications for the demanding onshore and offshore California markets.

A technically oriented article was published on the mineral requirements of the paint manufacturers in the United States, Western Europe, and Japan, for increasing specialized grades of materials.[28] The article also discussed the chemical and physical properties of the three main paint components: pigment, medium (binder or vehicle), and solvent (thinner). A special pigment section listed specifications for barite, blanc fixe, and lithopone, and also included detailed flowsheets used in their production. An interesting feature of the article was its description of the wide range of substitutability possible in pigment material to reduce raw material cost, yet still remain capable of producing high-quality competitive paint.

The technical rationale for the past, present, and future industrial minerals usage by the U.S. drilling industry[29] and North Sea Oilfields was published.[30] The U.S. drilling industry paper stressed the indispensibility of barite weighting agents and new material usages, such as organoclays and mineral-wool fibers. The North Sea paper attempted to forecast the future mineral requirements of the areas based on the technology of developing 80 new fields and 100 production platforms, and drilling up to 1,500 appraisal and development wells.

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# Bauxite and Alumina

## By Luke H. Baumgardner[1] and Ruth A. Hough[2]

For the major U.S. aluminum companies, 1985 was a year of restructuring and expansion into peripheral fields. There was increased interest in specialty aluminas for abrasives, ceramics, electronics, and refractories. Domestic and world production of bauxite and alumina declined from 1984 output levels, and world alumina capacity decreased by 7% with the closing of five plants in Japan and the United States. The permanent closure of three refineries reduced domestic annual alumina capacity by 30%, further increasing U.S. reliance on foreign sources of supply.

**Domestic Data Coverage.**—Domestic production data for bauxite and alumina are developed by the Bureau of Mines from three separate voluntary surveys of U.S. operations. Typical of these surveys are the quarterly and annual "Production of Bauxite" surveys. Of the six operations to which a survey form was sent, all responded, representing 100% of the 1985 U.S. bauxite production shown in tables 1, 2, and 18.

**Table 1.—Salient bauxite statistics**

(Thousand metric tons and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production: Crude ore (dry equivalent) | 1,510 | 732 | 679 | 856 | 674 |
| Value | $26,489 | $12,334 | $11,309 | $15,643 | $12,855 |
| Exports (as shipped) | 20 | 49 | 74 | 82 | 56 |
| Imports for consumption[1] | 12,802 | 10,122 | 7,601 | [r]10,228 | 7,944 |
| Consumption (dry equivalent) | 13,525 | 9,217 | 9,100 | 10,519 | 8,206 |
| World: Production | [r]85,347 | [r]79,318 | 78,644 | [p]88,173 | [e]85,133 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Excludes calcined bauxite. Includes bauxite imported to the U.S. Virgin Islands.

**Legislation and Government Programs.**—There were no changes in the National Defense Stockpile (NDS) goals for bauxite during the year. The goal for metal grade bauxite, Jamaica-type, was 21.3 million tons,[3] and for Suriname-type, 6.2 million tons. The goals for calcined abrasive grade and refractory grade were 1 million and 1.4 million tons, respectively. The General Services Administration (GSA) reported inventories at yearend of 12.7 million tons of Jamaica-type and 5.4 million tons of Suriname-type, metal grade bauxite. The final deliveries of metal grade, Jamaica-type bauxite were accepted for the stockpile by GSA, increasing the inventory in 1985 by 1.02 million tons. Deliveries of 76,000 tons of calcined refractory grade bauxite from China, purchased under two 1984 GSA contracts, began during the year but had neither been completed nor added to the inventory by yearend.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict that would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, two forms of bauxite would be listed in tier II.

The goal for metal grade bauxite would be 3.88 million tons of aluminum metal equivalent (identical to the 1985 yearend metal grade bauxite inventory), and the goal for calcined refractory grade bauxite would be 279,339 tons.

The Occupational Safety and Health Administration hazard communication standard went into effect on November 25. Domestic companies, including the bauxite and alumina industries, were to determine whether any of their products contained substances hazardous to their employees or customers, and if so, how they were to be labeled.

## DOMESTIC PRODUCTION

Production of bauxite in the United States was 674,000 tons, or about 21% lower than the 856,000 tons produced in 1984. Near Bauxite, AR, the Aluminum Co. of America (Alcoa) mined bauxite to supply its local alumina plant and to calcine for use in proppants and abrasives. Nearby at Bryant, AR, American Cyanamid Co. mined and calcined bauxite for shipment to the company's plants in Michigan and Illinois for the production of aluminum sulfate. The Porocel Corp. at Berger, AR, calcined bauxite purchased from a local supplier to produce activated bauxite used principally by the petroleum industry. In the southeastern bauxite mining district, Harbison-Walker Refractories Co., a division of Dresser Industries Inc., mined bauxite west of Eufaula, AL, for calcining to refractory material and as raw material feed for the production of proppants at another division of Dresser Industries, the plant in Eufaula. Mullite Co. of America mined bauxite in Henry County, AL, and in Sumter County, GA, for calcining to refractory grade bauxite at the company's plant near Andersonville, GA.

Domestic alumina production capacity was reduced by 1.935 million tons per year with the permanent closure of refineries by Martin Marietta Aluminum Inc. at St. Croix, VI, in May; by Ormet Corp. at Burnside, LA; and by Kaiser Aluminum & Chemical Corp. at Baton Rouge, LA, at yearend 1985. Of the nine domestic alumina plants that were in operation in 1982, only four were still operating at yearend 1985.

Total production of alumina (calcined equivalent) during the year declined to about 3.4 million tons, the lowest level since 1960. Based on an average annual capacity figure of 5.4 million tons, apparent capacity utilization in 1985 was about 64%.

### Table 2.—Mine production of bauxite and shipments from mines and processing plants to consumers in the United States

(Thousand metric tons and thousand dollars)

| Year | Mine production | | | Shipments from mines and processing plants to consumers[1] | | |
|---|---|---|---|---|---|---|
| | Crude | Dry equivalent | Value[2] | As shipped | Dry equivalent | Value[2] |
| 1983 | 826 | 679 | 11,309 | 977 | 913 | 26,370 |
| 1984 | 1,054 | 856 | 15,643 | 1,332 | 1,227 | 35,719 |
| 1985 | 787 | 674 | 12,855 | 993 | 989 | 34,506 |

[1] May exclude some bauxite mixed in clay products.

[2] Computed from values assigned by producers and from estimates of the Bureau of Mines.

### Table 3.—Recovery of dried, calcined, and activated bauxite in the United States

(Thousand metric tons)

| Year | Crude ore treated | Total processed bauxite recovered[1] | |
|---|---|---|---|
| | | As recovered | Dry equivalent |
| 1984 | 361 | 168 | 294 |
| 1985 | 329 | 166 | 284 |

[1] Dried, calcined, and activated bauxite. May exclude some bauxite mixed in clay products.

### Table 4.—Percent of domestic bauxite shipments, by silica content

| $SiO_2$ (percent) | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| From 8 to 15 | 65 | 63 | W | W | W |
| More than 15 | 35 | 37 | W | W | W |

W Withheld to avoid disclosing company proprietary data.

**Table 5.—Production and shipments of alumina in the United States**

(Thousand metric tons)

| Year | Calcined alumina | Other alumina[2] | Total[1] | |
|---|---|---|---|---|
| | | | As produced or shipped[3] | Calcined equivalent |
| Production:[e] | | | | |
| 1981 | 5,490 | 700 | 6,190 | 5,960 |
| 1982 | 3,810 | 465 | 4,280 | 4,130 |
| 1983 | 3,540 | 680 | 4,220 | 4,000 |
| 1984[r] | 4,160 | 560 | 4,720 | 4,545 |
| 1985 | 2,860 | 860 | 3,725 | 3,465 |
| Shipments:[e] | | | | |
| 1981 | 5,610 | 715 | 6,320 | 6,085 |
| 1982 | 3,730 | 420 | 4,150 | 4,020 |
| 1983 | 3,480 | 670 | 4,150 | 3,945 |
| 1984[r] | 4,230 | 570 | 4,800 | 4,620 |
| 1985 | 2,890 | 760 | 3,650 | 3,425 |

[e] Estimated. [r] Revised.

[1] Data may not add to totals shown because of independent rounding.

[2] Trihydrate, activated, tabular, and other aluminas. Excludes calcium and sodium aluminates.

[3] Includes only the end product if one type of alumina was produced and used to make another type of alumina.

**Table 6.—Capacities of domestic alumina plants,[1] December 31**

(Thousand metric tons per year)

| Company and plant | 1984 | 1985 |
|---|---|---|
| Aluminum Co. of America: | | |
| Bauxite, AR | 340 | 340 |
| Point Comfort, TX | 1,400 | 1,600 |
| Total | 1,740 | 1,940 |
| Martin Marietta Aluminum Inc.: St. Croix, VI | 635 | -- |
| Kaiser Aluminum & Chemical Corp.: | | |
| Baton Rouge, LA | 955 | -- |
| Gramercy, LA | 770 | 770 |
| Total | 1,725 | 770 |
| Ormet Corp.: Burnside, LA | 545 | -- |
| Reynolds Metals Co.: Corpus Christi, TX | 1,700 | 1,700 |
| Grand total | 6,345 | 4,410 |

[1] Capacity may vary depending upon the bauxite used.

## CONSUMPTION AND USES

Consumption of crude and dried bauxite declined substantially from 1984 levels as a direct result of reduced alumina demand and alumina plant closures. Calcined and activated bauxite consumption was about the same as that of 1984. Of the total bauxite consumed during the year, 987,000 tons, or 12%, went to refractories, abrasives, chemicals, proppants, and other nonalumina uses. The 27 U.S. primary aluminum smelters that operated during all or part of the year consumed about 82% of the total domestic alumina produced, while the remaining 634,000 tons (calcined equivalent) served as feedstocks to the abrasives, ceramics, chemicals, and refractories industries. As in 1984, the only domestic bauxite refined to alumina was mined and processed in Arkansas, and virtually all of the alumina produced was consumed in nonmetal uses.

The market for proppant sales to the U.S. petroleum industry, which looked promising in 1984, was beginning to weaken by yearend 1985 as domestic drilling slowed in response to lowered world oil prices. Demand for bauxite-based refractories by the steel industry, the principal user, exhibited no improvement during the 12-month period and characterized the flat or downward trend in consumption of all specialty bauxites.

## Table 7.—U.S. consumption of bauxite, by industry

(Thousand metric tons, dry equivalent)

| Industry | Domestic | Foreign | Total[1] |
|---|---|---|---|
| 1984: | | | |
| Alumina | 724 | 8,741 | 9,465 |
| Abrasive[2] | W | W | 328 |
| Chemical | [3]39 | [3]268 | 251 |
| Refractory | 119 | 301 | 420 |
| Other | W | W | 56 |
| Total[1] [2] | 977 | 9,542 | 10,519 |
| 1985: | | | |
| Alumina | 664 | 6,555 | 7,219 |
| Abrasive[2] | W | W | 305 |
| Chemical | [3]30 | [3]244 | 219 |
| Refractory | 111 | 297 | 408 |
| Other | W | W | 55 |
| Total[1] [2] | 868 | 7,338 | 8,206 |

W Withheld to avoid disclosing company proprietary data; included with "Chemical" or "Total."

[1] Data may not add to totals shown because of independent rounding.

[2] Includes consumption by Canadian abrasive industry.

[3] Includes "Other."

## Table 8.—U.S. consumption of crude and processed bauxite

(Thousand metric tons, dry equivalent)

| Type | Domestic origin | Foreign origin | Total[1] |
|---|---|---|---|
| 1984: | | | |
| Crude and dried | 826 | 9,007 | 9,833 |
| Calcined and activated | 151 | 535 | 686 |
| Total | 977 | 9,542 | 10,519 |
| 1985: | | | |
| Crude and dried | 729 | 6,797 | 7,526 |
| Calcined and activated | 140 | 541 | 680 |
| Total[1] | 868 | 7,338 | 8,206 |

[1] Data may not add to totals shown because of independent rounding.

## Table 9.—Production and shipments of selected aluminum salts in the United States, in 1984

| Item | Number of producing plants | Production (thousand metric tons) | Total shipments including interplant transfers | |
|---|---|---|---|---|
| | | | Quantity (thousand metric tons) | Value (thousands) |
| Aluminum sulfate: | | | | |
| Commercial and municipal (17% $Al_2O_3$) | 62 | 1,025 | 946 | $120,371 |
| Iron-free (17% $Al_2O_3$) | 19 | 103 | 85 | 10,711 |
| Aluminum chloride: | | | | |
| Liquid and crystal (32° Be) | 3 | 6 | W | W |
| Anhydrous (100% $AlCl_3$) | 4 | 19 | W | W |
| Aluminum fluoride, technical | 4 | W | W | W |
| Aluminum hydroxide, trihydrate (100% $Al_2O_3 \cdot 3H_2O$) | 7 | 609 | 612 | 161,573 |
| Other inorganic aluminum compounds[1] | XX | XX | XX | 59,553 |

W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1] Includes sodium aluminate, light aluminum hydroxide, cryolite, and alums.

Source: Data are based upon Bureau of the Census report Form MA-28A, "Annual Report on Shipments and Production of Inorganic Chemicals."

### Table 10.—Stocks of bauxite in the United States,[1] December 31

(Thousand metric tons, dry equivalent)

| Sector | 1984 | 1985 |
|---|---|---|
| Producers and processors | [r]499 | 413 |
| Consumers | [r]4,382 | 3,431 |
| Government | 17,338 | 18,357 |
| Total | [r]22,219 | 22,201 |

[r] Revised.

[1] Domestic and foreign bauxite; crude, dried, calcined, activated; all grades.

### Table 11.—Stocks of alumina in the United States,[1] December 31

(Thousand metric tons, calcined equivalent)

| Sector | 1984 | 1985 |
|---|---|---|
| Producers[e] | 229 | 194 |
| Primary aluminum plants | 1,485 | 1,438 |
| Total[e] | 1,714 | 1,632 |

[e] Estimated.

[1] Excludes consumers' stocks other than those at primary aluminum plants.

## PRICES

Metal grade bauxite is rarely traded on world commodity markets, and sales of metal grade calcined alumina are equally limited. Neither the inter- and intracompany long-term sales contracts nor the government-to-company contracts normally are made public. A few trade journals quote spot sales and prices of specialty forms of bauxite and alumina.

The average value in 1985 of domestic crude bauxite shipments, f.o.b. mine or plant, was estimated by the Bureau of Mines to be $16.53 per ton. The average value of calcined domestic bauxite was estimated to be $113 per ton. Base prices quoted by principal sales agents for imported calcined refractory grade bauxite ranged from $117 to $145 per ton, f.o.b. barge, Louisiana, for Chinese material, 85% $Al_2O_3$ typical. Guyana refractory bauxite, minimum 86% $Al_2O_3$, ranged in price from $154 per ton in January to $168 in December, f.o.b. car, Baltimore, MD, or f.o.b. barge, Burnside, LA. In each case, adjustments were applied to the base price for various grain-size specifications, size of order, and fuel cost factors.

The estimated average value of shipments of domestic calcined alumina was $179 per ton. Trade data of the Bureau of Census indicated an average value of $203 per ton, f.a.s. port of shipment, and $215 per ton, c.i.f. U. S. ports.

### Table 12.—Average value of U.S. imports of crude and dried bauxite[1]

(Per metric ton)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Port of shipment (f.a.s.) | Delivered to U.S. ports (c.i.f.) | Port of shipment (f.a.s.) | Delivered to U.S. ports (c.i.f.) |
| To U.S. mainland: | | | | |
| Australia | $14.76 | $23.70 | $14.72 | $23.35 |
| Brazil | 28.34 | 38.47 | 30.27 | 39.53 |
| Guinea | 28.85 | 36.42 | 29.76 | 36.26 |
| Guyana | 36.30 | 52.11 | 42.40 | 54.31 |
| Jamaica | 31.44 | 36.91 | 30.81 | 35.09 |
| Suriname | 38.22 | 48.27 | 37.09 | 48.26 |
| Weighted average | 29.79 | 36.99 | 28.95 | 35.72 |

[1] Computed from quantity and value data reported to U.S. Customs Service and compiled by the Bureau of the Census, U.S. Department of Commerce. Not adjusted for moisture content of bauxite or differences in methods used by importers to determine value of individual shipments.

### Table 13.—Market quotations on alumina and aluminum compounds

(Per metric ton, in bags, carlots, freight equalized)

| Compound | Dec. 31, 1984 | Dec. 30, 1985 |
|---|---|---|
| Alumina, calcined | $418.88 | $418.88 |
| Alumina, hydrated, heavy | 209.44 | 209.44 |
| Alumina, activated, granular, works | 905.00 | 905.00 |
| Aluminum sulfate, commercial, ground (17% $Al_2O_3$) | 259.04 | 259.04 |
| Aluminum sulfate, iron-free, dry (17% $Al_2O_3$) | 439.82 | 439.82 |

Source: Chemical Marketing Reporter.

## FOREIGN TRADE

Of the 7.9 million tons of crude and dried bauxite imported by the United States, Guinea supplied 47%; Jamaica, 29%; Australia, 10%; and Brazil, 7%. Although imports from Australia increased, compared with receipts in 1984, the quantity was not sufficient to offset the decline in imports from Brazil, Guyana, Jamaica, and Suriname.

China was the leading supplier of calcined refractory grade and abrasive grade bauxite imports, although a portion of the refractory bauxite was delivered to the NDS under a GSA purchase contract. Calcined abrasive grade bauxite imports from Australia were nearly the same as those of 1984. Guyana supplied a small amount of abrasive grade bauxite to the United States while imports from China more than doubled over those of 1984. Fused crude aluminum oxide, produced in Canada from calcined abrasive grade bauxite, was shipped to U.S. plants for the manufacture of abrasive and refractory end products.

Australia supplied 76% of the alumina imported for consumption and Jamaica, Suriname, and Canada, in order of decreasing quantities, accounted for most of the balance. Supplies from each of the four major source countries declined from the 1984 level.

Exports of dried bauxite totaled 31,819 tons, of which 59% was shipped to Canada and 37% to the Federal Republic of Germany. Of the 24,274 tons of calcined bauxite exported during the year, Mexico received 84%; France, 11%; and Canada, 5%. Exports of alumina dropped by 50% compared with 1984 exports, primarily as a result of reduced shipments to Norway. Canada and Mexico received about 72% of the exports. Other aluminum compounds exported included 5,700 tons of aluminum sulfate, 11,100 tons of aluminum oxide abrasives, and 32,400 tons of unclassified aluminum compounds, including aluminum fluoride and synthetic cryolite.

### Table 14.—U.S. exports of alumina,[1] by country

(Thousand metric tons, calcined equivalent, and thousand dollars)

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value |
| Argentina | ([2]) | 469 | 1 | 558 | ([2]) | 455 |
| Belgium-Luxembourg | 1 | 3,138 | 2 | 2,616 | 2 | 2,369 |
| Brazil | 21 | 5,881 | ([2]) | 268 | 1 | 821 |
| Canada | 25 | 19,664 | 80 | 37,238 | 132 | 36,185 |
| France | 3 | 3,474 | 2 | 3,412 | 1 | 2,717 |
| Germany, Federal Republic of | 3 | 6,086 | 3 | 6,008 | 4 | 6,732 |
| Ghana | 19 | 3,173 | -- | -- | -- | -- |
| Japan | 2 | 4,636 | 3 | 8,064 | 1 | 2,515 |
| Mexico | 99 | 29,697 | 111 | 33,376 | 104 | 29,115 |
| Netherlands | 2 | 2,690 | 11 | 4,017 | 3 | 4,021 |
| Norway | 265 | 59,794 | 369 | 81,228 | 45 | 7,417 |
| Sweden | 98 | 14,147 | 60 | 10,350 | 22 | 2,966 |
| United Kingdom | 4 | 4,195 | 3 | 4,014 | 3 | 5,361 |
| Venezuela | 52 | 12,287 | 4 | 2,833 | 1 | 1,192 |
| Other | 8 | 12,588 | 10 | 15,127 | 7 | 12,967 |
| Total[3] | 602 | 181,920 | 659 | 209,110 | 327 | 114,833 |

[1] Includes exports of aluminum hydroxide (calcined equivalent) as follows: 1983—8,100 tons; 1984—13,100 tons; and 1985—16,700 tons, and aluminum oxide abrasives.

[2] Less than 1/2 unit.

[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

### Table 15.—U.S. imports for consumption of bauxite, crude and dried,[1] by country

(Thousand metric tons)

| Country | 1983 | 1984 | 1985 |
|---|---|---|---|
| Australia | -- | 560 | 829 |
| Brazil | 555 | 786 | 560 |
| Guinea | 3,600 | 3,718 | 3,752 |
| Guyana | 167 | 264 | 225 |
| Jamaica[2] | 3,036 | [r]4,559 | 2,325 |
| Sierra Leone | -- | -- | 56 |
| Suriname | 239 | 325 | 176 |
| Other | 4 | 15 | 20 |
| Total[3] | 7,601 | [r]10,228 | 7,944 |

[r] Revised.

[1] Includes bauxite imported to the U.S. Virgin Islands from foreign countries.

[2] Dry equivalent of shipments to the United States.

[3] Data may not add to totals shown because of independent rounding.

Note: Total U.S. imports of crude and dried bauxite (including the U.S. Virgin Islands) as reported by the Bureau of the Census were as follows: 1983—7,903,202 tons; 1984—10,436,135 tons; and 1985—7,257,840 tons.

Source: Bureau of the Census.

### Table 16.—U.S. imports for consumption of calcined bauxite, by country

(Thousand metric tons and thousand dollars)

| Country | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Refractory grade | | Other grade | | Refractory grade | | Other grade | |
| | Quantity | Value[1] | Quantity | Value[1] | Quantity | Value[1] | Quantity | Value[1] |
| Australia | (2) | 281 | 24 | 2,928 | -- | -- | 23 | 3,705 |
| China | 78 | 7,428 | 18 | 1,389 | 169 | 13,131 | 41 | 2,077 |
| Guyana | 110 | 14,763 | -- | -- | 102 | 12,402 | 4 | 538 |
| Suriname | 1 | 154 | (2) | 4 | (2) | 8 | (2) | 11 |
| Other | -- | -- | (2) | 56 | (2) | 4 | (2) | 92 |
| Total[3] | 190 | 22,626 | 42 | 4,377 | 272 | 25,546 | 69 | 6,424 |

[1] Value at foreign port of shipment as reported to U.S. Customs Service.

[2] Less than 1/2 unit.

[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

### Table 17.—U.S. imports for consumption of alumina,[1] by country

(Thousand metric tons, calcined equivalent, and thousand dollars)

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value[2] | Quantity | Value[2] | Quantity | Value[2] |
| Australia | 3,049 | 544,322 | 3,055 | 593,722 | 3,014 | 564,261 |
| Brazil | 3 | 1,565 | 39 | 7,128 | 50 | 10,142 |
| Canada | 159 | 67,762 | 204 | 91,603 | 177 | 76,133 |
| France | 6 | 10,982 | 9 | 14,455 | 7 | 11,968 |
| Germany, Federal Republic of | 13 | 15,797 | 20 | 24,080 | 18 | 19,480 |
| Jamaica | 399 | 87,973 | 572 | 125,974 | 372 | 66,171 |
| Japan | 25 | 7,927 | 3 | 3,680 | 4 | 4,918 |
| Suriname | 318 | 59,225 | 392 | 75,317 | 326 | 42,949 |
| Venezuela | 35 | 4,394 | 116 | 15,158 | -- | -- |
| Other | 24 | 11,078 | 55 | 25,253 | 11 | 13,640 |
| Total[3] | 4,030 | 811,021 | 4,466 | 976,364 | 3,979 | 809,664 |

[1] Includes imports of aluminum hydroxide, crude aluminum oxide, and refined and ground aluminum oxide.

[2] Value at foreign port of shipment as reported to U.S. Customs Service.

[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

World production of bauxite by 23 countries totaled 85 million tons in 1985. Australia, Brazil, Guinea, and Jamaica, as in 1984, contributed about 68% of the world total, and these four countries also supplied about 94% of the U.S. crude and dried metal grade bauxite imports. Three of the world's 25 alumina-producing countries, Australia, the U.S.S.R., and the United States, accounted for nearly 50% of the 31.9 million tons of alumina produced.

In November, members of the International Bauxite Association (IBA) recommended minimum prices for bauxite and alumina. In 1986, the minimum for metal grade bauxite was to be 2.5% to 3.5% of a reference price for 99.5% primary aluminum ingot. The reference market price of metal was to be derived by using an average of spot prices and long-term prices from West European and U.S. markets. The minimum price range proposed for cell-grade alumina was 12% to 16% of the primary ingot price.

**Australia.**—Despite a sluggish year for the world aluminum industry, Australia increased bauxite production to 32.4 million tons from 32.2 million tons the previous year. Alumina production remained at about the same level as that of 1984. In Queensland, Comalco Ltd. produced 7.6 million tons of bauxite at its mining operations at Weipa. The calcining units at Weipa operated at about 86% of capacity, and the company shipped 230,000 tons of calcined abrasive grade bauxite. Reportedly, Comalco filed for a patent covering a new synthetic proppant with better physical characteristics than those of proppants currently produced from calcined bauxite. Queensland Alumina Ltd. (QAL)—owned by Comalco (30.3%), Kaiser (28.3%), Alcan Australia Ltd. (21.4%), and Pechiney (20%)—produced 2.1 million tons of alumina at the Gladstone, Queensland, refinery. QAL reduced production in April, but announced it was restarting the idle third unit during the last quarter of the year in order to meet commitments. At the Gove, Northern Territory, mine and refinery of Nabalco Pty. Ltd. (a Swiss Aluminium Ltd. subsidiary), bauxite production was 5.88 million tons, and alumina production, 1.26 million tons—both close to the 1984 output. More than one-half of the bauxite mined was locally processed into alumina.

Alcoa of Australia Ltd. announced that alumina production at its 1.4-million-ton-per-year Kwinana refinery in Western Australia would be reduced in the fourth quarter to an operating rate of about 70% of capacity. Production at the company's Pinjarra and Wagerup refineries was not affected, and Alcoa's total production for the year in Western Australia was 15.1 million tons of bauxite and about 4.6 million tons of alumina. Production by Worsley Alumina Pty. Ltd., owned by Reynolds Alumina Australia Ltd. (40%), Shell Co. of Australia Ltd. (30%), BHP Minerals Ltd. (20%), and Kobe Alumina Associates (Australia) Pty. Ltd. (10%), totaled 3.3 million tons of bauxite and 1.0 million tons of alumina. The Boddington gold deposit, discovered by the Worsley Alumina group during development of its bauxite reserves, reportedly could become one of Australia's major gold mining operations. Initial plans call for the annual production of more than 5,000 kilograms of gold per year. The company was reported to be awaiting approval of various permits after having been granted an environmental permit.

**Brazil.**—The 1985 bauxite production was about 6.7 million tons for this country controlling 10% of the world's bauxite reserves. Alumina production was approximately 1.0 million tons. Shell Brasil S.A. planned to invest $33 million in an expansion of the Alumínio do Maranhão S.A. (ALUMAR) refinery and primary smelter project at São Luis, in which the company held a 29% interest. The two other partners in ALUMAR were Alcoa Alumínio S.A. and Camargo Correa S.A. Bauxite was supplied to the 500,000-ton-per-year alumina plant from the Trombetas Mine under a contract with Mineração Rio do Norte S.A. (MRN), a consortium owned 46% by Cia. Vale do Rio Doce (CVRD) and a group of North American and West European companies. MRN, Brazil's only exporter of bauxite, produced and shipped an estimated 4.1 million tons of ore. At yearend, when the $28.50 per ton base price for Trombetas bauxite was due to expire, the Government, MRN, and its customers were negotiating to set a new contract price. Also in December, the 32 Japanese companies holding an interest in the Nippon Amazon Aluminium Co. (NAAC) postponed their decision for the third time on whether or not to proceed with the construction of the 800,000-ton-per-year Alumina do Norte do Brasil S.A. (ALUNORTE) alumina plant adjacent to the Alumínio Brasileiro S.A. (ALBRÁS) primary aluminum smelter that started production earlier in the year. ALBRÁS had signed contracts with the Suriname Aluminum Co. and Venezuela's Interamericana de Alúmina C.A. (INTERALUMINA) refinery to supply the smelter with alumina until 1990.

**China.**—The Government was reported to have signed an agreement calling for Pechiney of France to provide technical assistance for the Hejin alumina plant currently under construction in Shanxi Province. The refinery is expected to achieve the designed annual production rate of 660,000 tons by 1990. In 1985, bauxite deposits in Shanxi Province were reported to contain about 30% of China's resources. Contracts with foreign companies were being sought by the China National Nonferrous Metals Industry Corp. for the development of a number of mineral projects, including a mine, a 300,000-ton-per-year alumina plant, and a 100,000-ton-per-year primary aluminum smelter in Pingguo County, Guangxi Zhuang Autonomous Region. The $800 million vertically integrated project was planned to utilize power from a hydroelectric project on the Hong Shui River.

**Ghana.**—After the rebuilding of the railroad between the Awaso bauxite mine and the shiploading facilities at Takoradi on the coast was completed early in the year, ore production rose to 124,000 tons, a substantial increase over 1984 output, although considerably below the mine's annual capacity of 300,000 tons.

**Greece.**—The state agency, Hellenic Aluminium Industry S.A., responsible for the planned 600,000-ton-per-year alumina plant project, signed contracts under which the U.S.S.R. agreed to provide equipment and services for the construction of the plant and to buy 380,000 tons per year of the alumina produced for a period of 10 years. The foundation work for the plant had been started at Agia Efthimia, on the Gulf of Corinth, and the project was expected to take more than 4 years to complete.

**Guinea.**—Production from the three bauxite mines in Guinea was 13.1 million tons, with Compagnie des Bauxites de Guinée (CBG) contributing about 8.5 million tons of the total. Alumina production by the Frialco Co. was about 580,000 tons. Halco (Mining) Inc., 51% owner of CBG, continued discussions into December in an effort to persuade the Government of Guinea to reduce the $13 per ton levy currently imposed on Halco's bauxite production.

**Guyana.**—After 2 years in which bauxite production was slightly above 1 million tons, 1985 output increased to nearly 1.7 million tons. The U.S. firm, Green Construction Co., continued overburden removal under Government contract. No alumina was produced at the Linden refinery, which has remained dormant since it closed in 1982. However, Guyana entered negotiations during the year with the German Democratic Republic and a Brazilian company in a plan to reopen the 355,000-ton-per-year alumina plant. Estimated costs were reported to be between $12 and $20 million. Loans were being sought from the International Bank for Reconstruction and Development and from the European Economic Community to improve all areas of the country's bauxite and alumina industry. Guyana reported that it had reached an agreement to sell bauxite to the U.S.S.R. from 1986 through 1993. The final contract was to be signed early in 1986 and no terms or prices were announced in advance. In another agreement, the Bauxite Industry Development Co. (BIDCO), Guyana's state-owned sales organization, signed a 5-year contract with Reynolds International Services Inc., in which Reynolds was to serve as a consultant to BIDCO in technical, production, and marketing areas of the bauxite and alumina operations through 1989.

**Hungary.**—Bauxite production for the year was about 2.8 million tons, and alumina output was reported to be 801,000 tons. In November 1985, Hungary opened the Fenyoefoe No. 1 bauxite mine after 4 years of development and construction. At the designed production capacity of 650,000 tons per year, the reserves were expected to be depleted in approximately 40 years. About 70% of the ore production was to come from underground workings and the balance from open pit operations. Most of the output was expected to be processed at the Almasfuezitoe alumina plant. Production also started at Tatabanja's Nagyegyhaza bauxite mine in mid-1985. The open pit operation was expected to produce 150,000 tons by the end of the year, and 1986 production was scheduled to reach 350,000 tons. By 1987, after the underground operations started, output of 500,000 tons per year was planned. Ore from this mine was also to be processed at the Almasfuezitoe refinery.

**India.**—Bauxite production for the year was reported to be 2 million tons, and alumina output was about 560,000 tons. A substantial escalation in cost resulted from the delay in commissioning the Bharat Aluminium Co. (BALCO) bauxite mining project in Orissa. Officials associated with the project reported that instead of the planned May 1985 startup, the operation was expected to open in mid-1987. The Government of India approved new regulations to facilitate exports of bauxite and for the fiscal year 1986, exports totaling 400,000 tons of ore were scheduled. The U.S.S.R. agreed to provide both technical and financial help to India to assist in the bauxite and alumina project at Vishakapatnam. The project was to include a bauxite mine and refinery in Andhra Pradesh and a refinery in Orissa. Completion of the 800,000-ton-per-year facility in Orissa was scheduled for 1987 when the U.S.S.R. planned to start its annual purchases of 1 million tons of bauxite and 200,000 tons of alumina. The National Institute of Science, Technology, and Development issued a report recommending that India should develop Middle East alumina markets with smelters in Algeria, Bahrain, Dubai, Egypt, Iran, and Libya rather than increase its bauxite exports. The report noted that China could be a major potential market for India's aluminum industry after NAAC's new plant starts production in 1987.

**Jamaica.**—Bauxite production of 6.2 million tons and alumina production of 1.6 million tons were both lower than in 1984. When Alcoa closed its Claredon alumina plant for an indefinite period in February, the Government of Jamaica entered into negotiations with the company to bring the plant back into production. A 2-year contract was signed in which Alcoa was to operate the plant as a contractor to Clarendon Alumina Production Ltd., a newly formed state-owned company, and the refinery was reopened in August. Jamaica was reported to have found customers for the 200,000 tons of alumina produced during the balance of 1985 and was optimistic that 500,000 tons of the plant's 800,000 tons of annual capacity could be placed through European and Soviet sales in 1986. Kaiser and Reynolds Metals Co. bought out ARCO Metals Co.'s 27% share in the Alumina Partners of Jamaica (Alpart) refinery in mid-August and 2 weeks later announced the closing of the 1.3-million-ton-per-year plant.

**Japan.**—Alumina production in 1985 was reported to be 978,000 tons, the lowest since 1982. Sumitomo Aluminium Smelting Co. Ltd. announced that it was selling part of its 770,000-ton-per-year Kikumoto alumina plant to Sumitomo Chemical Co. and permanently closing down the major part of the facility. High operating costs were cited as the principal reason for the decision. Mitsui Aluminium Co. Ltd. closed its 400,000-ton-per-year Kitakyusha alumina plant after reaching an agreement with Nippon Light Metal Co. Ltd. to refine, under a tolling arrangement, the bauxite Mitsui had contracted to buy from Gove Alumina Ltd., Northern Territory, Australia.

**Venezuela.**—With initial funds allocated in 1984, C.V.G. Bauxita Venezolana C.A. (BAUXIVEN) began work in January 1985 on the development of the $360 million Los Pijiguaos bauxite mining project. Additional funding through a $108 million loan was approved by the Inter-American Development Bank late in 1985. In the first stage of development, the mine was to have an annual capacity of 3 million tons, and provision was made in the design of the mine and ore transport systems to expand output to 5 million tons per year. The first ore was expected to be barged down the Orinoco River to the INTERALUMINA plant at Puerto Ordaz in 1987, raising Venezuela's aluminum industry to a fully integrated status. The alumina plant was supplied with bauxite imported from Brazil, Guyana, Sierra Leone, and Suriname in 1985. Plans were reportedly under discussion for the expansion of the INTERALUMINA refinery by 300,000 to 500,000 tons per year to satisfy proposed increased capacity in the country's two primary aluminum smelters. In 1985, approximately 360,000 tons of alumina was exported and the balance of INTERALUMINA's 1.085-million-ton output was supplied to the local smelters.

## Table 18.—Bauxite: World production, by country[1]

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Australia | 25,441 | 23,625 | 24,372 | 32,182 | 32,400 |
| Brazil | 5,770 | 6,289 | 7,199 | 6,433 | 6,650 |
| China[e] | 1,500 | 1,500 | 1,600 | 1,600 | 1,650 |
| Dominican Republic[2] | 457 | 141 | -- | -- | -- |
| France | 1,827 | 1,662 | 1,663 | 1,607 | [3]1,484 |
| Germany, Federal Republic of | (4) | (4) | (4) | (4) | (4) |
| Ghana | 181 | 64 | 70 | 115 | 124 |
| Greece | 3,216 | 2,853 | 2,455 | 2,296 | 2,500 |
| Guinea[5] | 11,112 | 11,827 | 12,421 | 13,160 | 13,100 |
| Guyana[2] | 1,681 | 1,783 | 1,087 | 1,333 | 1,675 |
| Haiti[2] [6] | 427 | 377 | -- | -- | -- |
| Hungary | 2,914 | 2,627 | 2,917 | 2,994 | [3]2,815 |
| India | 1,923 | 1,854 | 1,923 | 1,994 | [3]2,038 |
| Indonesia | 1,203 | 700 | 778 | 1,003 | [3]830 |
| Italy | 19 | 23 | 23 | (7) | -- |
| Jamaica[2] [8] | 11,682 | 8,361 | 7,683 | 8,734 | 6,239 |
| Malaysia | 701 | 589 | 502 | 680 | 540 |
| Pakistan | 2 | [r]4 | 3 | 3 | 2 |
| Romania[e] | [3]712 | 680 | 650 | 620 | 600 |
| Sierra Leone | [e]610 | [r]631 | 785 | 1,000 | 800 |
| Spain | 9 | 7 | 5 | 7 | 7 |
| Suriname | [r]4,006 | [r]4,205 | 3,400 | 3,454 | 3,000 |
| Turkey | [r]590 | 508 | 306 | 132 | 132 |
| U.S.S.R.[e] [9] | 4,600 | 4,600 | 4,600 | 4,600 | 4,600 |
| United States[2] | 1,510 | 732 | 679 | 856 | [3]674 |
| Yugoslavia | 3,249 | 3,668 | 3,500 | 3,347 | [3]3,250 |
| Zimbabwe | 5 | 8 | 23 | 23 | 23 |
| **Total** | [r]85,347 | [r]79,318 | 78,644 | 88,173 | 85,133 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Table includes data available through July 8, 1986.

[2] Dry bauxite equivalent of crude ore.

[3] Reported figure.

[4] Less than 1/2 unit.

[5] Dry bauxite equivalent of ore processed by drying plant.

[6] Shipments.

[7] Revised to zero.

[8] Bauxite processed for conversion to alumina in Jamaica plus kiln-dried ore prepared for export.

[9] In addition to the bauxite reported in the body of the table, the U.S.S.R. produces nepheline syenite concentrates and alunite ore as sources of aluminum. Estimated nepheline syenite production was as follows, in thousand metric tons: 1981—2,500; 1982—2,500; 1983—2,500; 1984—2,500; and 1985—2,500. Estimated alunite ore production was as follows, in thousand metric tons; 1981—605; 1982—610 (revised); 1983—615; and 1984—615. Nepheline syenite concentrate grades 25% to 30% alumina, and alunite ore grades 16% to 18% alumina; these commodities may be converted to their bauxite equivalent by using factors of 1 ton of nepheline syenite concentrate equals 0.55 ton of bauxite and 1 ton of alunite equals 0.34 ton of bauxite.

## Table 19.—Alumina: World production,[1] by country[2]

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Australia | 7,079 | 6,631 | 7,231 | 8,781 | [3]8,792 |
| Brazil | 497 | 606 | 787 | 891 | 1,000 |
| Canada | 1,208 | [e]1,127 | 1,116 | 1,126 | 1,020 |
| China[e] | 750 | 800 | 800 | 800 | 825 |
| Czechoslovakia[e] | [r]90 | [r]80 | [r]80 | [r]85 | 85 |
| France | 1,095 | 960 | 853 | 898 | 875 |
| German Democratic Republic | 45 | 46 | 42 | 43 | 44 |
| Germany, Federal Republic of | 1,651 | 1,510 | 1,580 | 1,701 | 1,700 |
| Greece | [r]494 | [r]404 | 410 | 482 | 500 |
| Guinea | 608 | 549 | 583 | 508 | 580 |
| Guyana[4] | 157 | 73 | -- | -- | -- |
| Hungary | 792 | 710 | 836 | 811 | [3]801 |
| India[e] | 500 | 500 | 450 | 560 | 560 |
| Ireland | -- | -- | 66 | 653 | 560 |
| Italy | 786 | 698 | 466 | 607 | [3]555 |
| Jamaica | 2,556 | 1,758 | 1,851 | 1,749 | 1,622 |
| Japan | 1,344 | 959 | 1,065 | 1,172 | [3]978 |
| Romania[e] | 540 | 514 | 512 | 510 | 480 |
| Spain | 695 | [r]673 | 737 | 742 | 725 |
| Suriname | 1,165 | 1,055 | 1,129 | 1,208 | 1,000 |
| Turkey | 131 | 84 | 57 | 75 | 76 |

See footnotes at end of table.

### Table 19.—Alumina: World production,[1] by country[2] —Continued

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| U.S.S.R.[e] | 2,800 | 3,000 | 3,200 | 3,300 | 3,500 |
| United Kingdom | 90 | 88 | 93 | 105 | 100 |
| United States[e] | 5,960 | 4,130 | 4,000 | [r]4,545 | 3,465 |
| Venezuela | -- | -- | 560 | 1,139 | 1,085 |
| Yugoslavia | 1,037 | 1,017 | 1,010 | [e]1,000 | 1,000 |
| Total | [r]32,070 | [r]27,972 | 29,514 | 33,491 | 31,928 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Figures presented generally represent calcined alumina; exceptions are noted individually.

[2] Table includes data available through July 8, 1986.

[3] Reported figure.

[4] Calcined alumina, plus calcined alumina equivalent of alumina hydrate.

### Table 20.—World annual alumina capacity, by country

(Thousand metric tons, yearend)

| Country | 1983 | 1984 | 1985 |
|---|---|---|---|
| Australia | 7,910 | 9,750 | 9,750 |
| Brazil | 650 | 1,150 | 1,150 |
| Canada | 1,225 | 1,225 | 1,225 |
| China | 850 | 850 | 850 |
| Czechoslovakia | 100 | 100 | 100 |
| France | 1,320 | [r]1,060 | 1,060 |
| German Democratic Republic | 65 | 65 | 65 |
| Germany, Federal Republic of | 1,745 | 1,745 | 1,745 |
| Greece | 500 | 500 | 500 |
| Guinea | 700 | 700 | 700 |
| Guyana | 355 | 355 | 355 |
| Hungary | 895 | 895 | 895 |
| India | 675 | 675 | 675 |
| Ireland | 800 | 800 | 800 |
| Italy | 920 | 920 | 920 |
| Jamaica | 2,825 | 2,825 | 2,825 |
| Japan | 2,615 | [r]2,390 | 1,605 |
| Romania | 540 | 540 | 540 |
| Spain | 800 | 800 | 800 |
| Suriname | 1,350 | 1,350 | 1,350 |
| Taiwan | (1) | (1) | -- |
| Turkey | 200 | 200 | 200 |
| U.S.S.R. | 4,500 | 4,500 | 4,500 |
| United Kingdom | 140 | 140 | 140 |
| United States | 7,145 | 6,345 | 4,410 |
| Venezuela | 1,000 | 1,000 | 1,000 |
| Yugoslavia | 1,635 | 1,635 | 1,635 |
| Total | [r]41,460 | [r]42,515 | 39,795 |

[r]Revised.

[1] Revised to zero.

## TECHNOLOGY

The Bureau of Mines continued research on recovery of alumina from kaolinitic clay using hydrochloric acid. Because the calcining of the clay was estimated to consume about 12% of the total energy required to produce alumina, the Bureau examined direct pressure leaching of uncalcined clay as a possible means of reducing processing costs. Alumina extraction in excess of 90% was achieved at digestion temperatures ranging from 108° C to 225° C; however, some problems in filtering were encountered.[4] A technique was developed by the Bureau to dewater the red mud waste residue generated by Bayer process alumina plants. A red mud slurry sample from the processing of Jamaican bauxite was diluted to 10% from 20% solids and treated with a mixture of two commercial anionic, high-molecular-weight, polymer flocculants. The red mud and flocculants were mixed in a baffled vessel that discharged the flocculated slurry into a stainless steel trommel where the material was dewatered to a density of 27% solids. After 15 days of draining in a screen-capped column, the solids content increased to more than 40%.[5]

Laboratory and pilot plant research on the use of Jamaican clay and red muds from local alumina plants to produce ceramic products was described.[6] The author estimated that the world's Bayer plants were producing 40 million tons of red mud (dry basis) per year and stressed that new methods of disposing of this growing environmental problem must be found. Red mud from three different Bayer plants in Jamaica was blended with local clay, granulated in a heated atomizer, and pressed into tiles prior to firing at 1,180° C to 1,190° C in a kiln. The tests indicated that the ceramic products could have a content of more than 50% red mud.

Beneficiation of Guyana bauxite by washing to reduce total silica ($SiO_2$) content to 4.5% or less traditionally has resulted in the loss of 30% to 50% of the crude ore. The staff of Guyana Mining Enterprises Ltd. reported that froth flotation with carefully controlled pH limits could selectively recover a high-alumina, 2.5% $SiO_2$, 0.7% $Fe_2O_3$ concentrate from the plus 325-mesh fraction of the washer tailings. Such a concentrate was considered acceptable as chemical-grade bauxite or, after additional processing, as premium-grade calcined refractory bauxite.[7]

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[1] Physical scientist, Division of Nonferrous Metals.

[2] Mineral data assistant, Division of Nonferrous Metals.

[3] All quantities in this chapter are given in metric tons unless otherwise specified.

[4] Sawyer, D. L., Jr., and T. L. Turner. Pressure Leaching Alumina From Raw Kaolinitic Clay Using Hydrochloric Acid. BuMines RI 8978, 1985, 20 pp.

[5] Hood, G. D., G. M. Wileman, D. A. Stanley, and B. J. Scheiner. Dewatering of Red Mud. Paper in Recycle & Secondary Recovery of Metals, ed. by P. R. Taylor, H. Y. Sohn, and N. Jarrett. Metall. Soc., AIME, Warrendale, PA, 1985, pp. 655-664.

[6] Puskas, F. New Possibilities for the Utilization of Red Mud From Alumina Refineries. Int. Bauxite Assoc. Q. Rev., v. 10, No. 3, Jan.-Mar. 1985, pp. 25-27.

[7] Hinds, S. A., K. Husain, and N. Liu. Beneficiation of Bauxite Tailings. Paper in Light Metals 1985, ed. by H. O. Bohner. Metall. Soc. AIME, New York, 1985, pp. 17-30.

# Beryllium

## By Deborah A. Kramer[1]

The United States continued to be the leading world producer of beryllium ores and the leading producer and consumer of beryllium metal, alloys, and oxide. However, weak demand in the electronics industry, especially for beryllium-copper alloys, contributed to a decrease in domestic beryllium consumption. As a result, U.S. mine production declined moderately, and world production fell slightly.

Beryl imports, mainly from Brazil, increased moderately from the low level in 1984, and metal imports increased about 150%. Exports of beryllium metal increased dramatically to over three times those of 1984.

**Domestic Data Coverage.**—Domestic production data for beryllium are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Beryllium Mineral Concentrate and Beryllium Ore" survey. Of the 14 operations to which a survey request was sent, 13 responded, representing 100% of the total mine shipments shown in tables 1 and 5.

**Table 1.—Salient beryllium mineral statistics**

(Short tons of beryllium metal equivalent unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Beryllium-containing ores: | | | | | |
| Mine shipments | 293 | 218 | 267 | 241 | 230 |
| Imports for consumption, beryl[1] | 86 | 106 | 88 | 53 | 66 |
| Consumption, reported | 326 | 215 | 280 | 360 | 316 |
| Price, approximate, per short ton unit BeO, imported cobbed beryl at port of exportation | $94 | $121 | $126 | $88 | $87 |
| Yearend stocks | 98 | 214 | 281 | 226 | 199 |
| World: Production[1] | 424 | 360 | 398 | [p]395 | [e]387 |

[e]Estimated. [p]Preliminary.

[1]Based on a beryllium metal equivalent of 4% in beryl.

**Legislation and Government Programs.**—The General Services Administration added 30 short tons of beryllium metal to the National Defense Stockpile in 1985. At yearend, Government stocks were beryl, 17,987 tons; beryllium-copper master alloy, 7,387 tons; and beryllium metal, 290 tons. The National Defense Stockpile goals for these materials remained at 18,000 tons, 7,900 tons, and 400 tons, respectively.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict that would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, beryllium would be categorized in tier II, and the goal would be 437 tons of beryllium metal equivalent. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

The Environmental Protection Agency issued final regulations under the Clean Water Act for specified nonferrous metals manufacturing operations that limit the discharge of pollutants by existing and new operations into navigable waters and into publicly owned treatment works. Daily and monthly average maximum effluent limits for beryllium varied according to type of manufacturing operation and effluent source.[5]

## DOMESTIC PRODUCTION

Shipments of beryllium ores declined slightly from those of 1984. Production of beryllium metal and beryllium oxide ceramic material increased slightly, but beryllium-copper master alloy production declined significantly.

Brush Wellman Inc. remained the only major domestic producer of beryllium-containing ores. The company mined bertrandite ore from its Spor Mountain, UT, open pit and processed the ore and imported beryl into beryllium hydroxide at its Delta, UT, mill. According to its annual report, Brush Wellman processed 95,000 tons of bertrandite ore and recovered 377,000 pounds of beryllium contained in concentrate. At yearend, the company's ore reserves were estimated to be 5.65 million tons, with an average beryllium grade of 0.23%, which is equivalent to 0.64% beryllium oxide. A small quantity of beryl also was produced domostically.

Brush Wellman began excavation of two new pits at its Utah mine to develop reserves. The project, expected to cost about $10 million, was scheduled for completion in 1986.

The Cabot Wrought Products Div. of Cabot Corp. produced beryllium-copper and other beryllium alloys at its Reading, PA, plant. In October 1985, Cabot announced that it would sell most of its alloys and metals facilities, including its beryllium-copper alloy sector, as part of a restructuring program. The divestiture reportedly would include beryllium-copper alloy facilities at Reading, PA, and Kokomo, IN, as well as the recently completed rolling mill at Elkhart, IN.[6]

In November, Emery Energy Inc. acquired Moody Beryllium Corp., which owned a deposit of beryllium ore near the Brush Wellman mine in Utah. Depending on the availability of financing, the company planned to develop the deposit, containing an estimated 500,000 tons of ore, grading 0.64% beryllium oxide.

## CONSUMPTION AND USES

Beryllium consumption in 1985 declined from that of 1984, partially owing to a weakened demand in the electronics industry, a major consumer of beryllium-copper alloys.

Copper-based beryllium alloys, containing 0.5% to 2% beryllium, continued to be the most widely used beryllium products. These alloys were manufactured in a wide variety of shapes including bar, casting ingots, extrusions, plate, rod, strip, tube, and wire. Although properties differ depending on the alloy composition, they normally include high electrical and thermal conductivities and high resistance to corrosion, wear, and fatigue. Beryllium-copper alloy strip was used primarily to produce small parts for electronic and electrical applications by high-speed stamping methods. These parts, which include connectors, springs, and contact parts, were used in automotive, aerospace, radar, and telecommunications systems. Large-diameter beryllium-copper alloy rod and tube were used in oil and gas exploration equipment, marine equipment, and industrial equipment. Specific applications of the large-diameter products include drill collars, instrument housings, housings for undersea communications signal boosters, and heavy load bearings and bushings. Beryllium-copper alloy wire was used to manufacture current-carrying springs, electronic sockets, and test probes. Beryllium-copper alloy bar and plate were used in systems such as robotic welding machines and materials handling devices.

Beryllium also was used to make nickel- and aluminum-based alloys. Nickel-based alloys were used for electrical and electronic components that are subjected to elevated temperatures, including bellows, diaphragms, and thermostats. The beryllium-aluminum alloys were used to reduce magnesium losses during preparation of aluminum and magnesium alloys by forming a protective oxide coating that prevents air exposure of the molten alloy surface.

Metallic beryllium was used primarily in aerospace and defense applications such as optical systems for satellites, inertial guidance systems, X-ray sources, and detector windows. Beryllium's light weight, excellent thermal conductivity, and high stiffness-to-weight ratio were important for these applications.

Beryllium oxide ceramic material was used mainly as integrated circuit substrates in high-performance computers, microwave systems, automotive and defense electronics, aircraft engine components, and telecommunications systems. Properties of beryllium oxide ceramics that were important to these applications were excellent electrical insulating properties and high mechanical strength and hardness.

## PRICES AND SPECIFICATIONS

At the beginning of the year, the price quoted in Metals Week for beryl ore was $96 to $106 per short ton unit (20 pounds) of contained beryllium oxide. Late in December, this price was reduced to $85 to $100 per short ton unit.

At yearend, the following prices for beryllium materials were quoted in American Metal Market, in dollars per pound, except for beryllium-copper master alloy, which was given in dollars per pound of contained beryllium:

| | | |
|---|---|---|
| Vacuum cast ingot, 97% pure | | $225 |
| Metal powder, in 5,000-pound lots and 97% pure | | 196 |
| Beryllium-copper master alloy | | 144 |
| Beryllium-copper casting alloy | $5.10- | 5.70 |
| Beryllium-copper in rod, bar, wire | | 8.05 |
| Beryllium-copper in strip | | 7.25 |
| Beryllium-aluminum alloy, in 100,000-pound lots | | 236 |
| Beryllium oxide powder | | 55.70 |

## FOREIGN TRADE

Exports of beryllium alloys increased dramatically in quantity from those of 1984, but the average value declined. The Federal Republic of Germany, Spain, Sweden, and the United Kingdom were the primary destinations, accounting for 80% of the total U.S. exports.

### Table 2.—U.S. exports of beryllium alloys, wrought or unwrought, and waste and scrap,[1] by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (pounds) | Value (thousands) | Quantity (pounds) | Value (thousands) |
| Belgium-Luxembourg | 79 | $1 | 1,256 | $126 |
| Brazil | 1,125 | 8 | -- | -- |
| Canada | 2,824 | 208 | 2,233 | 336 |
| Finland | 47 | 6 | 35 | 5 |
| France | 8,062 | 937 | 4,632 | 802 |
| Germany, Federal Republic of | 2,627 | 325 | 17,685 | 1,674 |
| Hong Kong | 3,114 | 32 | 3,067 | 24 |
| India | 100 | 1 | 440 | 37 |
| Ireland | 1,497 | 26 | -- | -- |
| Israel | 246 | 4 | 3 | 1 |
| Italy | 6,726 | 52 | 382 | 12 |
| Japan | 7,386 | 609 | 2,279 | 489 |
| Korea, Republic of | 772 | 34 | 3 | 1 |
| Malaysia | -- | -- | 2,000 | 12 |
| Mexico | 1,227 | 12 | 643 | 11 |
| Netherlands | 4 | 15 | 271 | 65 |
| Portugal | 490 | 7 | -- | -- |
| South Africa, Republic of | -- | -- | 200 | 4 |
| Spain | -- | -- | 49,010 | 280 |
| Sweden | 6 | 1 | 17,450 | 73 |
| Switzerland | 433 | 23 | 1,642 | 209 |
| Taiwan | 1,051 | 14 | 4,405 | 51 |
| United Kingdom | 1,493 | 246 | 11,785 | 2,158 |
| Other | [r]6 | [r]1 | 7 | 5 |
| Total | 39,315 | 2,562 | 119,428 | 6,375 |

[r] Revised.

[1] Consisting of beryllium lumps, single crystals, powder; beryllium-base alloy powder; and beryllium rods, sheets, and wire.

Source: Bureau of the Census.

Beryl was the only beryllium raw material imported into the United States. Beryl imports increased from those of 1984, but the average value remained about the same. The average value of imported beryl in 1985 was $867 per ton; the value in 1984 was $884. Brazil continued to be the principal import source, representing over 76% of total beryl ore imports in 1985. In addition to ore imports, 111,458 pounds of wrought, unwrought, and waste and scrap beryllium valued at $265,029 were imported into the United States, of which 89% was imported from Brazil and 10% came from the United Kingdom. Imports of beryllium oxide or carbonate and other compounds, totaling 9,864 pounds and valued at $258,467, were received from the Federal Republic of Germany and the United Kingdom. Beryllium-copper master alloy imports of 15,930 pounds, valued at $66,579, were received from China.

Table 3.—U.S. import duties for beryllium

| Item | TSUS No. | Most favored nation (MFN) | | Non-MFN |
|---|---|---|---|---|
| | | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Ore and concentrate | 601.09 | Free | Free | Free. |
| Unwrought beryllium waste and scrap. | 628.05 | 8.5% ad valorem | 8.5% ad valorem | 25% ad valorem. |
| Beryllium, wrought | 628.10 | 9% ad valorem | 9% ad valorem | 45% ad valorem. |
| Beryllium-copper master alloy | 612.20 | 7.2% ad valorem | 6% ad valorem | 28% ad valorem. |
| Beryllium oxide or carbonate | 417.90 | 3.7% ad valorem | 3.7% ad valorem | 25% ad valorem. |
| Other beryllium compounds | 417.92 | 4% ad valorem | do | Do. |

Table 4.—U.S. imports for consumption of beryl, by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Argentina | -- | -- | 113 | $107 |
| Brazil | 744 | $680 | 1,262 | 1,077 |
| China | 264 | 238 | 102 | 96 |
| Madagascar | -- | -- | 11 | 13 |
| Portugal | 33 | 31 | -- | -- |
| Rwanda | -- | -- | 33 | 23 |
| South Africa, Republic of | 93 | 58 | 39 | 38 |
| Switzerland | 112 | 98 | 66 | 59 |
| Zimbabwe | 86 | 72 | 20 | 14 |
| Total | 1,332 | 1,177 | 1,646 | 1,427 |

Source: Bureau of the Census.

## WORLD REVIEW

The United States was the world's largest mine producer of beryllium. World beryl production, led by the U.S.S.R. and Brazil, was slightly higher than that of 1984. China also was thought to be a substantial producer, but production data were unavailable.

**Canada.**—Highwood Resources Ltd. completed a 1,600-foot decline at its Thor Lake beryllium-rare earth prospect near Yellowknife, Northwest Territory. Approximately 60% of the material extracted from the decline was considered to be ore grade, and bulk samples of this ore were to be tested in order to determine optimum beryllium and rare-earth recovery methods. Ore reserves at this deposit were estimated to be 1.8 million tons grading 0.85% beryllium oxide. Highwood Resources planned to begin plant construction in 1986.

**China.**—China planned to double its nonferrous metal production over the next 5 years. As a part of this development, China planned to construct a beryllium oxide plant in the Xinjiang Uygur autonomous region.

**Japan.**—Working through its Japanese subsidiary, Brush Wellman planned to construct a plant near Tokyo to manufacture beryllium-copper alloy coil, clad metals, and other copper alloys. The company planned to begin production in the fall of 1986, with the metals targeted towards the electronics market. Japan currently imports most of its requirements for beryllium-copper alloys.

Table 5.—Beryl: World production, by country[1]

(Short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina | 8 | 7 | 26 | [e]17 | 17 |
| Brazil | [r]940 | [r]1,251 | 1,039 | 1,551 | 1,650 |
| Madagascar[2] | [r] [e]55 | 75 | (3) | 51 | 55 |
| Mozambique | [r]8 | [r]9 | 7 | [r] [e]7 | 7 |
| Portugal | [r]19 | [r]13 | 8 | 11 | 11 |
| Rwanda | 65 | 76 | 85 | 49 | 55 |
| South Africa, Republic of | 134 | 64 | 28 | 1 | -- |
| U.S.S.R.[e] | 2,000 | 2,000 | 2,100 | 2,100 | 2,100 |
| United States[4] (mine shipments) | 7,834 | 5,451 | 6,665 | 6,030 | [5]5,738 |
| Zimbabwe | 46 | 57 | 52 | 21 | 55 |
| Total | [r]10,609 | [r]9,003 | 9,950 | 9,838 | 9,688 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] In addition to the countries listed, China produced beryl, and Bolivia and Namibia may also have produced beryl, but available information is inadequate to formulate reliable estimates of production. Nepal reports producing small amounts. Table includes data available through Apr. 15, 1986.

[2] Includes ornamental and industrial products.

[3] Less than 1/2 unit.

[4] Includes bertrandite ore, calculated as equivalent to beryl containing 11% BeO.

[5] Reported figure.

## TECHNOLOGY

A 6-pound beryllium structure was developed to support a 95-pound sensor system mounted on the U.S. Army's Scout helicopter. Brush Wellman received a contract to supply 1 year's requirement of these support blanks, which is estimated to be about 100 pieces worth approximately $2 million. This is one of the first large-scale applications of beryllium metal in a conventional weapons system. Beryllium was selected over aluminum alloy or graphite-epoxy composite material because of its light weight and rigidity, which eliminates shaking that could impair visual accuracy. As a result of this program, Brush Wellman invested $3 million in hot isostatic pressing capability at its Elmore, OH, plant.[4]

Cabot reportedly installed a direct chill casting unit at its Reading, PA, laboratory. This casting unit was the first unit installed as part of a $750,000 melting and casting pilot plant that will be used to experiment on high-quality beryllium-copper alloys. Castings produced by the direct chill method are expected to have a maximum weight of 5,000 pounds.

A review of the world beryllium industry was published that discussed the supply, demand, uses, and new developments in alloy, ceramic, and metallic products.[5]

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[1] Physical scientist, Division of Nonferrous Metals.

[2] Federal Register. Nonferrous Metals Manufacturing Point Source Category; Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards. V. 50, No. 183, Sept. 20, 1985, pp. 38276-38402.

[3] Crisafulli, T. Cabot Undertakes Major Revamping. Am. Met. Mark., v. 93, No. 201, Oct. 17, 1985, pp. 1, 11.

[4] Weiss, B. Beryllium Structure Being Used To Support Scout Sensor System. Am. Met. Mark., v. 93, No. 228, Nov. 25, 1985, p. 14.

[5] Griffiths, J. Beryllium minerals—demand strong for miniaturization. Ind. Miner. (London), No. 213, June 1985, pp. 41-51.

# Bismuth

## By James F. Carlin, Jr.[1]

Domestic production of bismuth was derived by processing bismuth-rich residues from the production of intermediate metallurgical products, such as lead bullion, which contain bismuth as a minor constituent. One company accounted for all domestic primary production. Consumption continued to be mostly in the Northern and Eastern United States. The aluminum, chemical, cosmetic, pharmaceutical, and steel industries were major users. Domestic consumption remained about the same, and the price generally declined during 1985.

**Domestic Data Coverage.**—Domestic production data for bismuth metal are developed by the Bureau of Mines from a voluntary survey of the only U.S. bismuth refinery. Production data are not published to avoid disclosing company proprietary data.

**Legislation and Government Programs.**—Government stocks remained at 2,081,298 pounds. The National Defense Stockpile goal remained at 2,200,000 pounds.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict that would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. The status of bismuth was deferred until further detailed studies could be made. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act of 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

Federal income tax laws provided a depletion allowance of 22% for domestic operations and 14% for U.S. companies producing in foreign countries.

**Table 1.—Salient bismuth statistics**

(Thousand pounds unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Consumption | 2,393 | 1,876 | 2,285 | 2,648 | 2,648 |
| Exports[1] | 79 | 53 | 306 | 312 | 269 |
| Imports, general | 2,436 | 2,026 | 1,972 | 1,948 | 1,999 |
| Price, average, domestic dealer, per pound | $2.32 | $1.61 | $1.72 | $4.27 | $5.18 |
| Stocks, Dec. 31: Consumer | 509 | 542 | 577 | 480 | 507 |
| World: Mine production[2] | [r]8,263 | 8,733 | 8,461 | [p]8,415 | [e]9,175 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Includes bismuth, bismuth alloys, and waste and scrap.

[2] Excludes the United States.

## DOMESTIC PRODUCTION

A single primary refinery operated by ASARCO Incorporated at Omaha, NE, accounted for all primary production. Small quantities of secondary bismuth were produced by several firms from bismuth scrap materials.

## CONSUMPTION AND USES

Domestic consumption remained at about the same level as that of 1984, which was the highest level since 1979, reflecting a continuation of the general economic improvement. The category of metallurgical additives registered a significant increase in usage, while the category of chemicals showed a moderate decrease.

**Table 2.—Bismuth metal consumed in the United States, by use**

(Thousand pounds)

| Use | 1984 | 1985 |
|---|---|---|
| Chemicals[1] | 1,573 | 1,325 |
| Fusible alloys | 609 | 610 |
| Metallurgical additives | 424 | 668 |
| Other alloys | 20 | 21 |
| Other[2] | 22 | 19 |
| Total | 2,648 | 2,643 |

[1] Includes industrial and laboratory chemicals, cosmetics, and pharmaceuticals.
[2] Includes experimental.

## PRICES

During the first 2 months of the year, the quoted dealer price of bismuth continued at the relatively high level that prevailed at the end of 1984, reportedly reflecting a tightened supply situation caused by several leading world producers diverting their bismuth to centrally planned economy countries at premium prices. By March, the price started a steady decline that continued throughout most of the year. Domestic dealer quotations were $6.50 to $6.70 per pound at the beginning of the year and finished the year at $3.50 to $3.80 per pound. The published price of a major foreign producer, Mining and Chemical Products Ltd. (United Kingdom), was $6.50 per pound until November when the firm suspended its list price.

## FOREIGN TRADE

Exports of bismuth declined moderately but still remained at the relatively high levels of the past 3 years. The United Kingdom remained the major export destination, accounting for about two-thirds of the exports. Imports continued to be the major supply for domestic consumption. Mexico remained the major source of U.S. imports, with Belgium-Luxembourg and the United Kingdom being substantial contributors.

Starting January 1, 1985, the U.S. import duties for bismuth were unwrought metal (TSUS 632.10), free for most favored nations (MFN) and 7.5% ad valorem for non-MFN; alloys (TSUS 632.66), 6.4% ad valorem for MFN and 45% ad valorem for non-MFN; and compounds (TSUS 418.00 and 423.80), 8.8% ad valorem for MFN and 35% ad valorem for non-MFN.

### Table 3.—U.S. exports of bismuth, bismuth alloys, and waste and scrap, by country

| Country | 1984 Quantity (pounds) | 1984 Value (thousands) | 1985 Quantity (pounds) | 1985 Value (thousands) |
|---|---|---|---|---|
| Belgium -Luxembourg | -- | -- | 41,850 | $160 |
| Brazil | -- | -- | 377 | 3 |
| Canada | 45,855 | $290 | 17,235 | 147 |
| Chile | -- | -- | 780 | 8 |
| China | -- | -- | 7,202 | 64 |
| Colombia | 98 | 1 | -- | -- |
| Germany, Federal Republic of | 47,690 | 172 | -- | -- |
| Greece | 2,000 | 6 | -- | -- |
| Hong Kong | 10 | 1 | 380 | 2 |
| India | -- | -- | 1,226 | 8 |
| Ireland | 100 | 1 | 32 | 16 |
| Israel | 245 | 2 | 957 | 6 |
| Italy | -- | -- | 245 | 3 |
| Japan | 2,462 | 14 | 7,532 | 51 |
| Korea, Republic of | 188 | 15 | -- | -- |
| Mexico | 1,200 | 17 | -- | -- |
| New Zealand | 40 | 1 | -- | -- |
| Peru | 300 | 3 | -- | -- |
| Singapore | 863 | 28 | 1,885 | 5 |
| South Africa, Republic of | 136 | 2 | 247 | 10 |
| Spain | 22,267 | 95 | 88 | 1 |
| Switzerland | 66,431 | 251 | -- | -- |
| Taiwan | 1,099 | 27 | 529 | 12 |
| Thailand | 82 | 4 | -- | -- |
| United Kingdom | 120,495 | 161 | 187,433 | 100 |
| Venezuela | -- | -- | 1,171 | 7 |
| Total | 311,511 | 1,091 | 268,669 | 603 |

Source: Bureau of the Census.

### Table 4.—U.S. general imports[1] of metallic bismuth, by country

| Country | 1984 Quantity (pounds) | 1984 Value (thousands) | 1985 Quantity (pounds) | 1985 Value (thousands) |
|---|---|---|---|---|
| Belgium-Luxembourg | 75,807 | $218 | 460,842 | $2,388 |
| Canada | 242,582 | 793 | 127,868 | 897 |
| China | 11,204 | 27 | 44,888 | 181 |
| Germany, Federal Republic of | 77,167 | 345 | 96,060 | 585 |
| Hong Kong | -- | -- | 7,725 | 38 |
| Japan | 209,193 | 557 | 99,430 | 496 |
| Korea, Republic of | 124,943 | 410 | 29,761 | 119 |
| Mexico | 430,518 | 1,124 | 678,155 | 2,928 |
| Peru | 391,813 | 924 | 173,306 | 910 |
| Spain | 493 | 2 | -- | -- |
| United Kingdom | 384,674 | 1,492 | 280,830 | 1,630 |
| Total | 1,948,394 | 5,892 | 1,998,865 | 10,172 |

[1] General imports and imports for consumption were the same in 1984 and 1985.

Source: Bureau of the Census.

## WORLD REVIEW

World production of bismuth rose slightly in response to increased demand. Australia remained the major producer of bismuth, although reportedly, bismuth-rich residues in Australia have been stockpiled in recent years.

Major world refiners included Dowa Mining Co. Ltd. and Mitsui Mining & Smelting Co. Ltd. in Japan, Empresa Minera del Centro del Perú in Peru, Industria Minera México S.A. and Industrias Peñoles S.A. de C.V. in Mexico, Korea Tungsten Mining Co. Ltd. in the Republic of Korea, Mining and Chemical Products in the United Kingdom, and Métallurgie Hoboken-Overpelt SA and Société Industrielle d'Etudes et d'Exploitations Chimique in Belgium.

### Table 5.—Bismuth: World mine production, by country[1]

(Thousand pounds)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Australia (in concentrates)[e] [3] | 2,600 | 3,310 | [r]3,110 | [r]2,980 | 3,090 |
| Bolivia (in concentrates) | 24 | 11 | 13 | [e]7 | 220 |
| Canada[4] | 370 | 417 | 445 | 485 | 440 |
| China (in ore)[e] | 570 | 570 | 570 | 570 | 570 |
| Japan (metal) | 1,054 | 1,071 | 1,263 | 1,241 | 1,370 |
| Korea, Republic of (metal) | 220 | 209 | 220 | 278 | 220 |
| Mexico[5] | 1,446 | 1,336 | 1,202 | 955 | 1,100 |
| Peru[5] | 1,409 | 1,351 | 1,179 | 1,473 | 1,650 |
| Romania (in ore)[e] | 180 | 180 | 180 | 180 | 180 |
| U.S.S.R. (metal)[e] | [r]165 | 170 | 180 | 180 | 185 |
| United States (metal) | W | W | W | W | W |
| Yugoslavia (metal) | 225 | 108 | 99 | 66 | [e]150 |
| Total | [r]8,263 | 8,733 | 8,461 | 8,415 | 9,175 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Table includes data available through Apr. 8, 1986.

[2]In addition to the countries listed, Brazil, Bulgaria, France, the German Democratic Republic, the Federal Republic of Germany, and Namibia are believed to have produced bismuth, but available information is inadequate for formulation of reliable estimates of output levels.

[3]In recent years, bismuth-rich residues have reportedly been stockpiled owing to weak demand and low prices.

[4]Refined metal and bullion plus recoverable bismuth content of exported concentrate.

[5]Bismuth content of refined metal, bullion, and alloys produced indigenously plus recoverable bismuth content of ores and concentrates exported for processing.

[6]Reported figure.

## TECHNOLOGY

A new procedure was developed to enhance high-quality, low-temperature soldering of electronic components on printed circuit boards. The procedure employs a 58% tin-42% bismuth eutectic alloy melting at 138° C and a rosin-free flux based on a sulfonated aromatic organic acid. These materials were shown to give superior mechanical joints.[2]

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[1]Physical scientist, Division of Nonferrous Metals.

[2]The Bulletin of the Bismuth Institute. No. 49, 1986, pp. 1-4.

# Boron

## By Phyllis A. Lyday[1]

U.S. production and sales of boron minerals and chemicals decreased during the year. Glass fiber insulation continued to be the largest use for borates, followed by textile-grade glass fibers, miscellaneous, and borosilicate glasses.

California was the only domestic source of boron minerals, mostly in the form of sodium borate, but also as calcium borate and calcium-sodium borates. The United States continued to provide essentially all of its own supply while maintaining a strong position as a source of sodium borate products and boric acid to foreign markets.

Supplementary U.S. imports of Turkish calcium borate and calcium-sodium borate ores and boric acid, primarily for various glass uses, continued.

**Domestic Data Coverage.—Domestic data for boron are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Of the three operations to which a production survey request was sent, all responded, representing 100% of the total boron sold or used shown in tables 1 and 7. A Bureau canvass of the three U.S. producers also collected data on domestic consumption of boron minerals and compounds shown in tables 2 and 3.**

**Table 1.—Salient statistics of boron minerals and compounds**

(Thousand short tons and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Sold or used by producers: | | | | | |
| Quantity: | | | | | |
| Gross weight[1] | 1,481 | 1,234 | 1,303 | 1,367 | 1,269 |
| Boron oxide ($B_2O_3$) content | 740 | 607 | 637 | 667 | 636 |
| Value | $435,387 | $384,597 | $439,181 | $456,687 | $404,775 |
| Exports: | | | | | |
| Boric acid: | | | | | |
| Quantity[2] | 46 | 35 | 38 | 45 | 49 |
| Value | $24,602 | $19,082 | $20,688 | $24,402 | $21,598 |
| Sodium borates: | | | | | |
| Quantity[3] | [4]228 | [4]227 | [4]225 | [r]576 | 623 |
| Value[e] | $58,000 | $59,000 | $51,000 | $134,000 | $151,000 |
| Imports for consumption:[5] | | | | | |
| Boric acid: | | | | | |
| Quantity | 1 | [r]2 | [r]4 | [r]4 | 6 |
| Value | $763 | $1,903 | $3,456 | $3,449 | $5,121 |
| Colemanite: | | | | | |
| Quantity | [r]22 | [r]2 | [r]16 | [r]20 | 33 |
| Value | $15,202 | $6,386 | $8,309 | $12,123 | $24,620 |
| Ulexite: | | | | | |
| Quantity | [r]18 | [r]14 | 11 | [r]47 | 31 |
| Value | $2,690 | [e]$2,800 | $3,116 | $10,202 | $11,120 |
| Consumption: Boron oxide ($B_2O_3$) content[6] | 373 | 266 | 341 | 375 | 360 |
| World: Production | 2,820 | 2,503 | 2,464 | [p]2,775 | [e]2,679 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Minerals and compounds sold or used by producers, including both actual mine production and a marketable equivalent of brine products.

[2]Includes domestic and imported orthoboric and anhydrous boric acid.

[3]Sources: 1981-83, U.S. Exporters; 1984-85, The Journal of Commerce Port Import/Export Reporting Service.

[4]Refined.

[5]Boron oxide ($B_2O_3$) content. Data for 1981-84 revised to indicate conversion to $B_2O_3$ content.

[6]See table 2.

**Legislation and Government Programs.**—A U.S. Environmental Protection Agency standard of emission performance for new stationary sources of nonmetallic mineral processing plants included new, modified, and reconstructed boron facilities. The affected facilities were each crusher, grinding mill, screening operation, bucket elevator, belt conveyor, bagging operation, storage bin, and enclosed truck or railcar loading station.[2]

## DOMESTIC PRODUCTION

Boron minerals, sold or used, decreased in quantity and value during the year. The majority of the output continued to be from Kern County, CA, with the balance from San Bernardino and Inyo Counties, CA.

American Borate Co., a wholly owned subsidiary of Owens-Corning Fiberglas Corp., continued to mine colemanite, a calcium borate, and probertite-ulexite, two similar calcium-sodium borates mined and sold as one, at its Billie Mine in Death Valley National Monument. The mine had a capacity of 350,000 short tons of ore containing 130,000 tons of salable product per year. Colemanite was ground and processed at the washing and calcining plant at Amargosa, NV. The plant had a capacity of 6,300 tons per month of concentrate. A flotation plant adjacent to existing facilities at Amargosa prepared colemanite by a patented process. The colemanite product was trucked to Dunn, CA, for blending, storing, and shipping by rail primarily to manufacturers of textile-grade glass fibers. Probertite-ulexite ore also was trucked to Dunn, where it was ground, screened, and blended to specification, stored, and shipped by rail to customers. Most shipments of the blended probertite-ulexite were to manufacturers of glass fiber insulation. American Borate announced a temporary closure of all borate mining and processing operations that would be in effect during 1986. The closure would affect about 300 employees at 4 locations, including the headquarters at Las Vegas, NV. The reasons cited for the closure were the strength of the U.S. dollar, which had the effect of increasing worldwide prices of boron minerals, and the increase in world supply. The length of the closure would depend upon future market conditions.

Kerr-McGee Chemical Corp. operated the Trona and Westend plants at Searles Lake, in San Bernardino County, to produce refined sodium borate compounds and boric acid from the mineral-rich lake brines. At the Trona plant, a differential evaporative process was used to produce boric acid, pentahydrate borax, and anhydrous borax. Byproducts included potassium compounds. One of the evaporative boilers continued to produce pentahydrate borax by extracting heat from process steam used in other operations to produce distilled water that could be recycled through a closed loop system. The Westend plant continued production of boric acid and produced sodium borates by a carbonation process that also produced lime, soda ash, and sodium sulfate. Production capacity was 210 tons per day of the combined borate products. Screening and grinding facilities were at both plants. Shipments were by rail via a company-owned spur to the Santa Fe Railroad at Ridgecrest, CA. Borates were marketed by Kerr-McGee under the trade names Three Elephant Borax, Three Elephant V-Bor, and Three Elephant Pyrobor.

United States Borax & Chemical Corp., a member of the RTZ Group of London, United Kingdom, continued to be the primary world supplier of sodium borates. U.S. Borax mined and processed crude and refined hydrated sodium borates, their anhydrous derivatives, and anhydrous boric acid at Boron, in Kern County, CA. Production of crude sodium borates—Rasorite 46, a pentahydrate, and its anhydrous derivative—were discontinued for sale in foreign markets because new trade laws allowed refined borax to enter Europe duty-free. Installation of equipment to improve the recovery of borax from the tailings was completed in 1984, becoming operational in 1985. Centrifuges separated clay matter from borax in aqueous solution. The borax was recovered by evaporating in solar ponds. The process increased borax recovery by 6% to an estimated total recovery of 91% of the ore processed.

A second plant at Boron used a proprietary process to produce technical-grade boric acid and waste sodium sulfate from U.S. Borax's extensive kernite ore reserves. Boric acid was produced to compete with the colemanite used in glass manufacture. The boric acid plant, the world's largest, lowered energy requirements by using kernite ore as feed. Kernite required less energy than borax because it was processed into boric acid as an ore.

Shipments from Boron were via the Santa Fe Railroad. The majority of material was shipped to U.S. Borax's storage, loading, and shipping facilities at Wilmington, CA. The Wilmington facility also produced some boron specialty chemicals and borated soap products. U.S. Borax marketed domestic borates under the Twenty Mule Team trade name.

Duval Corp., which was dissolved and renamed Pennzoil Sulphur Co. in 1985, sold its solution mining project at Newberry Springs, CA, to Mountain States Mineral Enterprises Inc. Mountain States was able to obtain private investors to proceed with the boric acid pilot project.

## CONSUMPTION AND USES

U.S. consumption of borates decreased. Glass fiber insulation and glass fiber reinforcement for plastics continued to be the largest consuming industries.

The use of borates in thermal insulation for new construction decreased. Glass fiber insulation was the largest area of demand for borates. Cellulosic insulation, the fifth largest area of demand, also decreased. Owens-Corning, a major glass fiber producer, acquired Armco Inc.'s Aerospace and Strategic Materials Group, which included Hitco Fabricated Composites Div., for $415 million. The purchase made Owens-Corning a producer of advanced composite materials. Composites are glass, graphite, boron, and aromatic polyamide (aramid) fibers with organic matrix resins. Hitco, which was fully integrated in composites, supplied resins, fibers, fabrics, preimpregnated fabrics, and shapes.[3]

The second major market for borates, manufacturing high-tensile-strength glass fiber materials for use in a range of products, showed an increase in demand. Composites allowed the designer to tailor structures to meet applied loads more effectively through deliberate fiber orientation, and more efficiently by reducing fiber content where loads are moderate. Composites in aerospace have been growing for more than 30 years because of their high specific strength and specific modulus, excellent corrosion and fatigue resistance, and design flexibility. These qualities have made composites ideally suited to numerous aerospace primary and secondary structures. Thus, weight may be decreased in certain structures by 20% to 50%. Typical glass fiber tensile strengths can exceed 400,000 pounds per square inch (psi) and elastic modulus of 10 million psi. Glass fibers tend to limit flight speeds to less than 200 miles per hour. In comparison, boron filaments, created by slow deposition of boron vapor on tungsten filaments, offer nearly 60-million-psi elastic modulus and about 500,000-psi tensile strength.[4]

Other uses of boron in glass fibers included asphalt roofing shingles, accounting for about 60% of asphalt-roofing sales in 1983. Glass fiber screens accounted for about 65% of the market in window and door screens, particularly in the Sunbelt States.[5]

White Consolidated Industries Inc. redesigned its dishwasher line and all of its brands, which included White-Westinghouse Appliance Co., Frigidaire Co., Gibson Appliance Co., and Kelvinator Appliance Co., and which were expected to use glass fiber composites on the inner door.

Consumption of borates in borosilicate glasses remained the fourth major end use, and demand increased. Complex glass batch calculations for borosilicate glasses were performed on microcomputers. The computerized glass formulations procedure had the advantages of improved accuracy of formulation when many complex raw materials were employed, established tolerance limits for each oxide level, and the capability to incorporate physical and chemical parameters into the batch formulation process.[6]

Boron compounds in cleaning and bleaching were also an important consumption sector. In addition, boron compounds continued to find application in the manufacture of biological growth control chemicals for use in water treatment, algicides, fertilizers, herbicides, and insecticides.

### Table 2.—U.S. consumption of boron minerals and compounds, by end use

(Short tons of boron oxide content)[1]

| End use | 1984 | 1985 |
|---|---|---|
| Agriculture | 15,003 | 15,003 |
| Borosilicate glasses | 32,418 | 34,629 |
| Enamels, frits, glazes | 11,172 | 12,295 |
| Fire retardants: | | |
| Cellulosic insulation | 29,150 | 26,522 |
| Other | 1,752 | 298 |
| Glass fiber insulation | 117,451 | 103,490 |
| Metallurgy | 4,132 | 3,307 |
| Miscellaneous uses | 20,615 | 22,521 |
| Nuclear applications | 1,107 | 1,088 |
| Soaps and detergents | 28,705 | 24,548 |
| Sold to distributors, end use unknown | 43,226 | 44,147 |
| Textile-grade glass fibers | 69,870 | 71,785 |
| Total | 374,601 | 359,633 |

[1] Includes imports of boric acid, colemanite, and ulexite.

### Table 3.—U.S. consumption of orthoboric acid, by end use

(Short tons of boron oxide content)

| End use | 1984 | 1985 |
|---|---|---|
| Agriculture | 142 | 194 |
| Borosilicate glasses | 5,730 | 11,015 |
| Enamels, frits, glazes | 410 | 1,335 |
| Fire retardants: | | |
| Cellulosic insulation | 6,598 | 4,770 |
| Other | 1,694 | 274 |
| Insulation-grade glass fibers | 516 | 144 |
| Metallurgy | 703 | 382 |
| Miscellaneous uses | 11,998 | 11,284 |
| Nuclear applications | 926 | 932 |
| Soaps and detergents | 605 | 424 |
| Sold to distributors, end use unknown | 15,864 | 16,181 |
| Textile-grade glass fibers | 17,403 | 18,360 |
| Total | 62,589 | 65,295 |

### Table 4.—Borate prices per short ton[1]

| Product | Price, Dec. 31, 1985 (rounded dollars) |
|---|---|
| Borax, technical, anhydrous, 99%, bulk, carlots, works[2] | 602 |
| Borax, technical, anhydrous, 99%, bags, carlots, works[2] | 647 |
| Borax, technical, granular, decahydrate, 99.5%, bags, carlots, works[2] | 232 |
| Borax, technical, granular, decahydrate, 99.5%, bulk, carlots, works[2] | 187 |
| Borax, technical, granular, pentahydrate, 99.5%, bags, carlots, works[2] | 259 |
| Borax, technical, granular, pentahydrate, 99.5%; bulk, carlots, works[2] | 214 |
| Boric acid, technical, granular, 99.9%, bags, carlots, works[2] | 614 |
| Boric acid, technical, granular, 99.9%, bulk, carlots, works[2] | 569 |
| Boric acid, United States Borax & Chemical Corp., high-purity anhydrous, 99% $B_2O_3$, 100-pound bags, carlots, Boron, CA | 2,297 |
| Colemanite, American Borate Co., calcined, minus 70-mesh, 45% $B_2O_3$, bulk, f.o.b. railcars, Dunn, CA | 502 |
| Colemanite, American Borate Co., concentrate (uncalcined), minus 70-mesh, 38% $B_2O_3$ f.o.b., Dunn, CA | 327 |
| Colemanite, Turkish, 40% to 42% $B_2O_3$, ground to a minus 70-mesh, f.o.b. railcars, Kings Creek, SC | 400 |

[1] U.S. f.o.b. plant or port prices per short ton of product. Other conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiation and/or somewhat different price quotations.

[2] Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 228, No. 25, Dec. 16, 1985, p. 41.

Boron compounds were also used in metallurgical processes as fluxes, as shielding slag in the nonferrous metallurgical industry, and as components in electroplating baths. Small amounts of boron and ferroboron were constituents of certain nonferrous alloys and specialty steels, respectively. Milward Alloy Inc. of Lockport, NY, began construction of a plant to produce titanium-boron master alloy rod that is widely used in the grain refining of wrought aluminum products. The plant was scheduled to begin production on January 1, 1986. General Motors Corp. (GM) announced the construction of a manufacturing plant for the production of a neodymium-iron-boron magnet that has been trademarked Magnequench. The facility was to be completed in May 1986. The new magnet would substitute for the traditional copper-coil-wound electromagnets used in starter motors for automobile engines. Weight savings of approximately 5 pounds per motor were expected. GM also planned to offer the magnets for nonautomotive uses.[7]

Many important but low volume end uses of borates and boron-containing chemical derivatives comprised a diverse miscellaneous category that included ceramics. Dow Corning Corp. purchased a ceramics firm, Boride Products Inc., that manufactured boron carbide devices used in industrial nozzles and other structural applications. Dow announced plans to spend $5 to $25 million to become established in ceramics. Other major companies that reported use of boron in ceramics were Advanced Refractory Technologies, Babcock & Wilcox Co., Corning Glass Works, PPG Industries Inc., and United Technologies Corp.[8]

## FOREIGN TRADE

Owens-Corning, through its American Borate subsidiary, imported boric acid, colemanite, and ulexite from Turkey, principally for use in textile-grade and insulation-grade fibers. Brokers also imported Turkish colemanite.

### Table 5.—U.S. exports of boric acid and refined sodium borate compounds, by country

| Country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Boric acid[1] | | Refined sodium borates[2] (short tons) | Boric acid[1] | | Sodium borates[2] (short tons) |
| | Quantity (short tons) | Value (thousands) | | Quantity (short tons) | Value (thousands) | |
| Argentina | 1 | $1 | -- | -- | -- | -- |
| Australia | 1,145 | 685 | 6,917 | 1,428 | $826 | 8,326 |
| Belgium-Luxembourg | -- | -- | -- | -- | -- | 74 |
| Brazil | 160 | 128 | 3,187 | 8 | 5 | 3,387 |
| Canada | 7,657 | 3,902 | [3]54,398 | 4,826 | 2,560 | [3]51,392 |
| Chile | 2 | 4 | 783 | -- | -- | 138 |
| China | -- | -- | -- | 20 | 12 | 11,353 |
| Colombia | 299 | 191 | 2,237 | 239 | 147 | 5,024 |
| Costa Rica | 7 | 6 | 42 | -- | -- | 438 |
| Denmark | 21 | 12 | -- | 64 | 37 | -- |
| Dominican Republic | -- | -- | -- | -- | -- | 44 |
| Ecuador | 64 | 37 | 563 | 4 | 3 | 845 |
| El Salvador | 2 | 3 | 22 | 10 | 6 | 40 |
| Finland | -- | -- | 2 | -- | -- | -- |
| France | 44 | 82 | [r]1 | 3 | 1 | -- |
| German Democratic Republic | -- | -- | 1 | -- | -- | -- |
| Germany, Federal Republic of | 168 | 278 | -- | 6 | 18 | -- |
| Guatemala | -- | -- | 173 | -- | -- | 62 |
| Haiti | 12 | 5 | -- | -- | -- | 77 |
| Honduras | 37 | 13 | -- | -- | -- | 62 |
| Hong Kong | 329 | 180 | 3,037 | 209 | 122 | 2,323 |
| India | 9 | 3 | 6,884 | -- | -- | 11,590 |
| Indonesia | 81 | 46 | 4,834 | 144 | 78 | 5,126 |
| Iran | -- | -- | -- | 21 | 12 | -- |
| Israel | 36 | 21 | 376 | 25 | 15 | 309 |
| Italy | -- | -- | 2 | -- | -- | -- |
| Jamaica | 13 | 11 | -- | 25 | 3 | -- |
| Japan | 23,748 | 13,732 | 52,464 | 21,701 | 12,796 | 61,073 |
| Kenya | -- | -- | 27 | -- | -- | -- |
| Korea, Republic of | 1,223 | 685 | 8,113 | 1,186 | 731 | 18,209 |
| Madagascar | -- | -- | -- | -- | -- | 78 |
| Malaysia | 24 | 26 | 2,237 | 18 | 16 | 3,866 |
| Mexico | 3,002 | 1,336 | [3]21,741 | 3,815 | 1,868 | [3]21,678 |
| Netherlands | 40 | 68 | 341,325 | -- | -- | 360,264 |
| New Zealand | 1,914 | 837 | 3,318 | 2,113 | 972 | 3,250 |
| Nicaragua | -- | -- | 91 | -- | -- | 66 |
| Pakistan | -- | -- | 306 | -- | -- | 233 |
| Panama | 10 | 10 | 59 | 20 | 6 | 9 |
| Papua New Guinea | 128 | 57 | [r]183 | 84 | 42 | 198 |
| Peru | 3 | 2 | 46 | 6 | 4 | 34 |
| Philippines | 252 | 222 | 1,360 | 68 | 46 | 1,065 |
| Puerto Rico | -- | -- | 605 | -- | -- | -- |
| Saudi Arabia | -- | -- | -- | -- | -- | 465 |
| Singapore | 199 | 111 | 1,690 | 7 | 5 | 2,947 |
| South Africa, Republic of | 787 | 8 | 3,818 | 11 | 26 | 3,866 |
| Spain | -- | -- | 42,415 | -- | -- | 42,323 |
| Sri Lanka | 7 | 4 | 12 | 12 | 7 | 8 |
| Sweden | 64 | 37 | 114 | -- | -- | -- |
| Taiwan | 1,537 | 861 | 10,377 | 1,664 | 936 | -- |
| Thailand | 157 | 107 | 667 | 167 | 110 | 1,454 |
| Trinidad | -- | -- | -- | 11,200 | 5 | 78 |
| United Kingdom | 20 | 15 | 122 | -- | -- | 123 |
| Uruguay | 131 | 48 | 26 | 4 | 4 | 38 |
| Venezuela | 1,378 | 680 | 1,648 | 354 | 189 | 1,107 |
| Zimbabwe | -- | -- | -- | -- | -- | 339 |
| Other | 16 | 6 | 11 | -- | -- | -- |
| Total[4] | 44,728 | 24,403 | [r]576,231 | 49,457 | 21,598 | 623,375 |

[r] Revised.
[1] Bureau of the Census.
[2] The Journal of Commerce Port Import/Export Reporting Service data.
[3] U.S. exporters of sodium borates.
[4] Data may not add to totals shown because of independent rounding.

### Table 6.—U.S. imports for consumption of boric acid, by country

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (short tons) | Value[1] (thousands) | Quantity (short tons) | Value[1] (thousands) |
| Canada | ([2]) | ([2]) | 73 | $56 |
| France | 139 | $110 | 219 | 196 |
| Germany, Federal Republic of | 86 | 87 | 51 | 63 |
| Italy | 2,287 | 965 | 1,873 | 1,039 |
| Japan | ([2]) | 7 | -- | -- |
| New Zealand | -- | -- | 44 | 25 |
| Turkey | 5,236 | 2,280 | 8,058 | 3,665 |
| United Kingdom | ([2]) | ([2]) | ([2]) | ([2]) |
| U.S.S.R. | -- | -- | 105 | 76 |
| Total | 7,748 | 3,449 | 10,423 | [3]5,121 |

[1] U.S. Customs declared values.
[2] Less than 1/2 unit.
[3] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

Borates in the form of borax and ulexite occur in two geologic types of deposits in Peru, Argentina, Bolivia, and Chile. Thirty-five "salars" and fifteen "spring apron" type deposits have been identified. The distinction between the two was theorized to be a function of the distance that boron-bearing fluids traveled from the source to deposition of the boron minerals.[9]

**Bolivia.**—The Government authorized the Complejo Industrial de los Recursos Evaporíticos del Salar de Uyuni to seek international bids for the exploration, development, industrialization, and marketing of the salts of the Salar de Uyuni. The 7,000-square-kilometer area in southwestern Bolivia was reported to contain the largest and highest grade reserves of lithium salts in the world, and boron reserves were estimated at 3.5 million tons.

**Chile.**—A second major brine project in the Salar de Atacama in northern Chile was planned for production of boric acid, lithium carbonate, potassium chloride, and potassium sulfate. Negotiations commenced in 1984 and an agreement was reached in 1985 between AMAX Exploration Inc. and Molíbdenos y Metales S.A. to begin a feasibility study.

**China.**—A complex to be built in Kaifeng for the manufacture of glass fiber, which uses boron, was projected to cost between $75 and $90 million. Design of the complex was to be a joint venture named Heery/ITL of Heery International, and Innovative Engineers Ltd., both of Atlanta, GA. The complex was to be the first in the world to make glass fiber, thermosetting resins, and finished products in the same location. Initially about one-half of the production was planned for the domestic market, with 100% expected to be used in China within 7 years.

**India.**—The only source of borax in the country was in the Puga Valley in the Province of Kashmir at an altitude of 14,500 feet. Associated with the borax was gypsum, which was used to produce sulfur. Over 6 tons per day of borax was processed in plants in Jammu.

**Turkey.**—The borate mines were operated by Etibank, the Turkish state mining organization. Exports in 1984 totaled $101.77 million, or 35% of Turkish mineral export revenues. A new mining law was enacted on June 15, 1985, that replaced the 1954 legislation and amended both the 1978 law that nationalized many mining activities, including borates, and the 1983 law that returned some mines for exclusive State development, excluding borates. Development of foreign investment in Turkish minerals remained optimistic. After the change in the mining law, the Government became more oriented towards private sector investment by allowing exploration for borates, although the existing borate mining operations continued to be excluded from foreign investment. Newly discovered reserves of boron could be privately owned, but the mined output must be sold to Etibank for marketing. Because of Turkey's limited resources and extensive needs, the availability of external financing for public and private capital investment was expected to be a crucial factor in the future.

The boron derivatives plant at Kirka was continuing through a startup phase. The feed was from a surface tincal mine with an annual capacity of 1.3 million tons of ore, from which was produced about 830,000 tons of concentrate. The average ore content was 25% boron oxide ($B_2O_3$). The 10% clay fraction of the ore was removed by cyclones, classifier, and centrifuge dryer to produce a concentrate that averages 32% $B_2O_3$. About 55 tons per hour of concentrate was fed into the plant at full capacity. The plant, which produces anhydrous borax, was designed by Garrett AiResearch Manufacturing Co., of the United States, and engineered by a Turkish company. A 3.2-million-kilowatt-per-hour powerplant supplied the energy needs of the plant. Etibank planned to be capable of operating at full capacity by yearend 1985.[10]

### Table 7.—Boron minerals: World production, by country[1]

(Thousand short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina | 138 | 136 | 125 | 157 | 155 |
| Chile | 4 | (2) | 1 | 4 | 4 |
| China[e] | 30 | 30 | 30 | 30 | 30 |
| Peru[e] | 18 | 15 | 11 | 11 | 11 |
| Turkey | 929 | 868 | 774 | 986 | 990 |
| U.S.S.R.[e] | 220 | 220 | 220 | 220 | 220 |
| United States[3] | 1,481 | 1,234 | 1,303 | 1,367 | [4]1,269 |
| Total | 2,820 | 2,503 | 2,464 | 2,775 | 2,679 |

[e] Estimated. [p] Preliminary.

[1] Table includes data available through May 27, 1986.

[2] Less than 1/2 unit.

[3] Minerals and compounds sold or used by producers, including both actual mine production and a marketable ore equivalent of brine products.

[4] Reported figure.

## TECHNOLOGY

A new process for producing kraft pulp for paper production was developed by the Finnish Paper Institute. The lime circuit of the kraft process can be eliminated and the process simplified by using 20 pounds of borax for every ton of pulp produced. About 80% of the North American preduction of about 40 million tons per year of pulp was by the kraft process. The process would be economical for new plant construction or replacement of kilns.[11]

Amorphous boron transformer materials, usually alloys composed of iron, boron, and silicon with optional additions of cobalt or nickel, showed greatly reduced magnetic losses at high frequencies. The cobalt, iron, silicon, and boron materials are useful for magnetic recording head applications.[12]

Owing to their stiffness-to-weight and strength-to-weight ratios, boron-aluminum composites were considered as a structural replacement for titanium in advanced gas turbine engines. One approach to improving metal matrix composite toughness was to develop stronger and larger diameter fibers by secondary fiber treatment. Larger diameter boron fibers were produced by chemical vapor deposition; however, these fibers have generally displayed tensile strengths of the commercial boron fiber standard.[13]

U.S. Borax began production on a film in cooperation with the Bureau of Mines entitled "Boron—the Light-Heavyweight." Prints of the film are available for circulation to secondary schools, colleges, and other interested organizations.[14]

A conference on Advanced and Engineered Ceramics, held at Tuscaloosa, AL, discussed boron nitride powders for advanced applications. Also included were titanium-boride materials for applications in severe conditions of temperature, pressure, and environment.[15]

Boride ceramics tailored to meet particular applications showed properties of hardness, strength, and chemical stability. The annual production of boron carbides has been about 500 tons per year, with the dominant production process being carbothermic reduction. The chemical stability of diborides in Hall-Heroult cells for aluminum production, together with their wettability by liquid aluminum and high electrical conductivity, was promising. Energy savings of 25% have been demonstrated using titanium-boride replacement for graphite cathodes.[16]

Two finer grades of zinc borate synergist were in experimental production. The 3- to 15-micrometer material was intended for use as a flame retardant and smoke suppressant where nonimpairment of physical characteristics is critical. A zinc borate coated with a proprietary epoxy material was used in the wire and cable industry.[17]

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[5] Chemical Week. Chemicals: The New Foundation for Housing Starts. V. 137, No. 14, 1985, pp. 6-10.

[6] Lehman, R. L. Microcomputers Can Be Used To Optimize Batch Formulation. Glass Ind., v. 66, No. 8, 1985, pp. 14-17.

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[11] Janson, J. Auto Causticing Alkali and Its Use in Pulping and Bleaching Paper. Puu (Finland), v. 61, 1979, p. 495.

[12] White, R. M. Opportunities in Magnetic Materials. Science, v. 229, 1985, pp. 11-15.

[13] DiCarolo, J. A. Fibers for Structurally Reliable Metal and Ceramic Composites. J. Met., v. 37, No. 6, 1985, pp. 44-49.

[14] U.S. Department of the Interior, Bureau of Mines. News Release. May 23, 1986; contact Ann Englund (202) 634-1008.

[15] Ceramic Industry. Raw Materials for Advanced and Engineered Ceramics. V. 125, No. 5, 1985, pp. 32-33.

[16] Robbins, J. Advanced Ceramics—A Plea To Know More. Ind. Miner. (London), No. 211, 1985, pp. 75-81.

[17] Modern Plastics. Flame Retardants. V. 62, No. 9, 1985, pp. 63-65.

# Bromine

## By Phyllis A. Lyday[1]

Of the 835 million pounds of bromine produced worldwide in 1985, the United States produced 38%, followed by Israel, 26%; the U.S.S.R., 18%; the United Kingdom, 7%; six other countries accounted for the remainder of world output. The U.S. portion of world production has decreased since 1973, when the United States produc-

**Table 1.—Salient bromine and bromine compound statistics**

(Thousand pounds and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Bromine sold:[1] | | | | | |
| Quantity | 60,790 | ([2]) | ([2]) | ([2]) | ([2]) |
| Value | $11,000 | ([2]) | ([2]) | ([2]) | ([2]) |
| Bromine used: | | | | | |
| Quantity | 316,307 | ([2]) | ([2]) | ([2]) | ([2]) |
| Value | $75,100 | ([2]) | ([2]) | ([2]) | ([2]) |
| Exports: | | | | | |
| Elemental bromine: | | | | | |
| Quantity | W | NA | [3]4,500 | [4]68,200 | [4]6,252 |
| Value | W | NA | [3]$1,000 | [e]$15,200 | [e]$1,400 |
| Bromine compounds: | | | | | |
| Gross weight | 67,500 | [5]55,600 | [5]61,300 | [5]53,200 | [5]61,000 |
| Contained bromine | 56,000 | [5]47,200 | [5]52,000 | [5]45,100 | [5]51,900 |
| Value | $33,100 | [5]$21,100 | [5]$21,600 | [5]$16,200 | [5]$23,400 |
| Imports: | | | | | |
| Ammonium bromide: | | | | | |
| Gross weight | 678 | 1,599 | 1,634 | 1,450 | 2,786 |
| Contained bromine | 553 | 1,304 | 1,333 | 1,183 | 2,729 |
| Value | $436 | $989 | $962 | $854 | $1,593 |
| Calcium bromide: | | | | | |
| Gross weight | 22 | 82 | 1,722 | 1,598 | 5,093 |
| Contained bromine | 18 | 65 | 1,377 | 1,278 | 4,072 |
| Value | $6 | $40 | $900 | $203 | $917 |
| Potassium bromate: | | | | | |
| Gross weight | [r]362 | 390 | 679 | 661 | 1,069 |
| Contained bromine | 174 | 187 | 325 | 350 | 512 |
| Value | $323 | $336 | $572 | $610 | $899 |
| Potassium bromide: | | | | | |
| Gross weight | 107 | 281 | 436 | 367 | 968 |
| Contained bromine | 72 | 189 | 293 | 246 | 650 |
| Value | $80 | $204 | $303 | $268 | $685 |
| Sodium bromide: | | | | | |
| Gross weight | 20 | 645 | 2,534 | 1,916 | 2,901 |
| Contained bromine | 16 | 501 | 1,927 | 1,488 | 2,253 |
| Value | $12 | $423 | $971 | $851 | $1,108 |
| Other: | | | | | |
| Gross weight | 7,933 | 6,191 | 12,070 | 15,150 | 10,087 |
| Contained bromine | 4,755 | 4,060 | 10,241 | 11,535 | 6,863 |
| Value | $4,068 | $3,953 | $8,105 | $8,210 | $5,863 |
| World: Production | 758,346 | [r]843,963 | 801,863 | [p]873,550 | [e]835,090 |

[e] Estimated. [p] Preliminary. [r] Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1] Elemental bromine sold as such to nonproducers, including exports, or used in the preparation of bromine compounds by primary U.S. producers.

[2] Bromine sold or used estimated at 401 million pounds in 1982, valued at $103 million; 370 million pounds in 1983, valued at $91 million; 385 million pounds in 1984, valued at $95 million; and 320 million pounds in 1985, valued at $80 million.

[3] Bureau of the Census.

[4] The Journal Commerce Port Import/Export Reporting Service.

[5] Bureau of the Census. Includes methyl bromide and ethylene dibromide.

ed 71% of the world supply. The decrease in world share has been a result of environmental regulations and the emergence of Israel as a major producer. In 1985, five companies operated nine bromine producing plants in Arkansas and Michigan. The quantity of bromine sold or used in the United States was about 320 million pounds valued at $80 million. Exports of bromine contained in compounds amounted to 52 million pounds. Prices of elemental bromine in bulk were listed between 33 and 34.5 cents per pound. Primary uses of bromine compounds were as a scavenger for lead in gasoline, oil and gas well fluids, and flame retardants.

**Domestic Data Coverage.**—Domestic data for bromine are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the nine operations to which a survey request was sent, all responded, representing 100% of total elemental bromine sold or used.

**Legislation and Government Programs.**—The Environmental Protection Agency (EPA) ordered the quantity of lead in gasoline to be reduced to 0.1 gram per gallon by January 1, 1986.[2] Regulated lead reductions posed a concern to the bromine industry because they had the effect of decreasing demand for a major bromine chemical, ethylene dibromide (EDB), as a lead scavenger in automotive engines.

On March 12, use of EDB as a fumigant on certain fruits and vegetables was canceled.[3] An extension for use of EDB on mangoes was denied. An EPA position paper to the U.S. Department of State stated that as of September 1, "Imported mangoes with EDB residues would be prohibited from entry into the United States."[4]

The U.S. Department of Agriculture was in the process of computerizing a directory of ground water research projects. The data were being compiled on 46 Federally funded projects. Included in the study were four reports on EDB and three reports on dibromochloropropane (DBCP).[5]

Yearend legislation to renew the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund), which had expired at yearend 1984, was still under consideration. One of the concerns was the inequities of the law that allowed taxes to be avoided on imported chemical intermediates. During 1984, only 7 of the 20 largest volume organic chemical imports had been taxed under the existing law, yet these chemicals contribute to pollution.[6]

EPA proposed to amend regulations under the Resource Conservation and Recovery Act (RCRA) by listing two wastes generated during the production of methyl bromide.[7]

The Occupational Safety and Health Administration (OSHA) determined that the current permissible workplace exposure limit of 20 parts per million (ppm) of EDB did not provide workers adequate protection against cancer and other adverse health effects. OSHA was in the process of reviewing provisions to be included in the final standard.[8]

EPA granted Arkansas final RCRA authorization effective January 25 that delegated to the State dual State-Federal regulatory authority. EPA was to continue administering and enforcing the prohibition requirements of the Hazardous and Solid Waste Amendments until the State receives authorization.[9]

Great Lakes Chemical Corp. filed a third-party complaint against EPA in the U.S. District Court for the Western District of Washington at Seattle alleging that the agency was liable for damages the plaintiffs assert resulted from contamination of ground water with EDB. The three causes of action against the agency were as follows: breach of contract and implied warranties; exceeding statutory authority; and negligence, trade libel, and commercial disparagement.[10]

## DOMESTIC PRODUCTION

Three companies comprising the U.S. Bromine Alliance accounted for over 99% of U.S. elemental bromine capacity. Great Lakes had become the largest producer in 1981 with its acquisition of the bromine assets of Velsicol Chemical Corp., giving Great Lakes a major control of total domestic plant capacity that included Arkansas Chemicals Inc. In 1985, Great Lakes, The Dow Chemical Co., and Ethyl Corp. accounted for 43%, 32%, and 24% respectively, of plant capacity. Plant capacity did not reflect production capacity, which was dependent upon brine supplies, bromine concentration in the brine, and individual plant extraction processes. Arkansas brines contained about 5,000 ppm and Michigan brines about 2,600 ppm of bromine. The only other domestic elemental bromine producer was Morton Thiokol Inc., which was the only domestic producer of some inorganic bromides.

Dow operated one plant in Arkansas and two in Michigan. Plans continued to phase out brine production at the Midland, MI, plant in 1986 and to continue brine operations at Ludington, MI, and Magnolia, AR.

**Table 2.—Bromine producing plants in the United States in 1985**

| State and company | County | Plant | Production source | Elemental bromine plant capacity[1] (million pounds) |
|---|---|---|---|---|
| Arkansas: | | | | |
| Arkansas Chemicals Inc | Union | El Dorado | Well brines | 50 |
| The Dow Chemical Co | Columbia | Magnolia | do | 110 |
| Ethyl Corp | do | do | do | 160 |
| Great Lakes Chemical Corp | Union | El Dorado | do | 105 |
| Do | do | Marysville | do | 80 |
| Do | do | El Dorado | do | 50 |
| Michigan: | | | | |
| The Dow Chemical Co | Mason | Ludington | do | 20 |
| Do | Midland | Midland | do | 85 |
| Morton Thiokol Inc | Manistee | Manistee | do | 5 |
| Total | | | | 665 |

[1] Chemical Marketing Reporter. Chemical Profile. V. 228, No. 4, 1985, pp. 53-54.

## CONSUMPTION AND USES

Demand for EDB decreased because of reduced demand for leaded gasoline as a consequence of the regulation of lead concentration. New regulations were to begin January 1, 1986, that would allow 0.1 gram of lead per gallon of gasoline. The bromine-to-lead ratio in gasoline used in the United States has averaged 0.386, or 1 pound of bromine for approximately every 2.59 pounds of lead. Domestic production in 1985 was estimated at 103 million pounds of EDB containing about 88 million pounds of bromine for domestic and exported consumption. Ethyl closed its remaining Baton Rouge, LA, antiknock manufacturing units and exported leaded antiknock products produced by E. I. du Pont de Nemours & Co. Inc. through a joint venture agreement that included all domestically produced antiknocks.

The 1983 ban on EDB for fumigant and certain pesticide uses had brought about substitution with methyl bromide. Domestic methyl bromide consumption was estimated at 42.5 million pounds in 1985. Ethyl and Great Lakes were the sole domestic producers with 8 and 36 million pounds of capacity, respectively. Dow had closed 21 million pounds of capacity at Midland, MI, in 1983. Distribution of methyl bromide in 1985 was as follows: soil fumigant, 65%; space fumigant, 15%; chemical manufacturing, 10%; and exports, 10%.[11]

Inorganic synergists containing bromine fulfilled a need to produce fire retardant products that reduce smoke by enhancing the effectiveness of the active agent. The emphasis was on brominated compounds that boost performance but do not affect basic properties. Brominated compounds were used to make fire retardants for a wide variety of thermoplastics such as polycarbonate, polypropylene, nylon, polystyrene, epoxies, polyesters, urethanes, and polyethylene terephthalate. For example, alkyl ethers and methacrylate esters of brominated bisphenol-A and vinyl bromide were used in the production of fire retardants for thermoplastics. During 1985, domestic consumption of bromine compounds in flame retardants, reported by the Fire Retardant Chemicals Association, was 37.4 million pounds. Bromofluorocarbon fire extinguishers were more versatile than sodium bicarbonate or carbon dioxide extinguishers because they could be used on all classes of fires, were nontoxic, and left no residues.[12]

Solids-free bromide solutions formulated in densities of 11 to 15.5 pounds per gallon were used alone or in combination with calcium chloride in "completion" and "workover" fluids for oil and gas wells. Accounting for between 25% and 30% of domestic bromine consumption, the fluids have been developed to only about 5% of their potential market in oil and gas drilling.[13] However, the plunge in oil prices reduced well completions and decreased consumption of bromine compounds in drilling. Until 1982, sodium bromide had been used mainly in chemicals for photography, water treatment, pharmaceuticals, bleaching agents, and the formulation of other inorganic and organic chemicals; its usage in well completion had been limited to wells in Alaska and offshore California. Bromide well completion fluids were often used in the last 100 feet of drilling as a substitute for barite mud because they are clear, do not contaminate the oil-bearing formation, and have enough density to contain the formation pressures. Drillers commonly used sodium bromide, calcium bromide, or zinc-calcium bromide. If calcium was present in the formation, the introduction of calcium bromide could cause the well to plug in some instances; therefore, sodium bromide was used most widely. About 80% of the demand for sodium bromide in 1985 was in well drilling.

Bromine chloride was considered more effective than other chlorine chemicals in killing microorganisms and was nonirritative to the eyes and nose. Bromochlorodimethyl hydantoin was being sold as a sanitizer for pools, spas, and hot tubs. A brominated compound was also used as a preservative-inhibitor in emulsions and dispersions.

AmeriBrom Inc. was seeking registration of dibromonitrilopropionamide as a biocide. Consumption of chemicals in water and waste water treatment was estimated at $2 billion. A report by Frost & Sullivan Inc. forecast the market to rise by 6.5% per year. Chlorine was forecast to continue to be the most widely used disinfectant, but use of hypochlorites and other halogens such as bromine was expected to grow four times as fast.[14]

Other uses of bromine included a bromine compound used as an intermediate in the manufacture of metaphenoxybenzaldehyde for production of synthetic pyrethroids, such as fenvalerate, cypermethion, decamethrin, and permethrin. Potassium bromide and sodium bromide emulsions were used in photographic films, plates, and papers. Potassium bromate was also used in photographic film development.

One brominated dye was reported in use as an organic pigment in "Synthetic Organic Chemicals, 1984," published by the U.S. International Trade Commission. Pigment Red No. 168 was reported to have been produced by Mobay Chemical Corp., Dyes and Pigments Div.

## PRICES

Bromine was sold under contracts negotiated between buyer and seller. Price quotations do not necessarily represent prices at which transactions actually occurred, nor do they represent bid and asked prices. They were quoted here to serve only as a guide to yearend price levels.

### Table 3.—Yearend 1985 prices for elemental bromine and selected compounds

| Product | Value per pound (cents) |
|---|---|
| Ammonium bromide, National Formulary (N.F.), granular, drums, carlots, truckloads, freight equalized | 131 |
| Bromine, purified: | |
| Carlots, truckloads, delivered | 75 |
| Drums, carlots, truckloads, delivered east of the Rocky Mountains[1] | 87 |
| Bulk tank car, tank trucks (45,000-pound minimum), delivered east of the Rocky Mountains[1] | 33- 34.5 |
| Bromochloromethane, drums, carlots, f.o.b. Midland, MI | 112 |
| Calcium bromide, bulk, 14.2 pounds per gallon at 60° F, f.o.b. works[2] | 21- 36 |
| Ethyl bromide, technical, 98%, drums, carlots, freight allowed, East | 76 |
| Ethylene dibromide, drums, carlots, freight equalized | 38- 46 |
| Hydrobromic acid, 48%, drums, carlots, truckloads, f.o.b. works | 38.5 |
| Hydrogen bromide, anhydrous, cylinders, extra 30,000 pounds, f.o.b. works | 700 |
| Methyl bromide, distilled, tanks, 140,000-pound minimum, freight allowed | 56.75 |
| Potassium bromate, granular, powdered, 200-pound drums, carlots, f.o.b. works | 106 |
| Potassium bromide, N.F., granular, drums, carlots, f.o.b. works | 112 |
| Sodium bromide, 99% granular, 400-pound drums, freight, f.o.b. works | 104 |

[1] Delivered prices for drums and bulk shipped west of the Rocky Mountains, 1 cent per pound higher. Bulk truck prices 1 to 2.5 cents per pound higher for 30,000-pound minimum and 4 to 5.5 cents per pound higher for 15,000-pound minimum.

[2] Reported to the Bureau of Mines by primary producers.

Source: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 228, No. 25, Dec. 16, 1985, pp. 40-48.

## FOREIGN TRADE

EPA granted a one-time extension of 4 months for exports to Japan of domestic citrus fruit treated with EDB. Japan had refused to accept cold-treated citrus as a substitute because of the damage cold treatment had caused to 1984 shipments.[15]

Israel has enjoyed a margin of tariff preference for imports of bromine compounds into Japan of 7.9% to 9.6% more than U.S. producers. When the staged reductions agreed to during the Multilateral Trade Negotiations are completed, the range in the margin of preference was expected to be reduced to between 3.8% and 7.9% because Israeli bromine chemicals enter Japan duty free. U.S. producers had increased tetrabromobisphenol-A prices to Japan by 12% in 1983 and by 17% in 1984. A similar pattern of price increases had prevailed for other major flame retardants. U.S. producers, in effect, set their prices, c.i.f. Japanese port, to be competitive with the Japanese import price of Israeli products.[16] For all products, U.S. prices, excluding duty, increased more rapidly but, nevertheless, remained below Israeli prices. Adding the duty differentials to U.S. prices actually raised them above the Israeli prices.[17] Israeli flame retardants had been sold out until 1984, but increased Israeli production capacity was expected to change the market share in Japan in favor of Israel.

On June 11, the United States-Israeli Free Trade Area Agreement (Public Law 99-47) was signed into law. The agreement will eliminate customs duties on all trade between the two countries during a 10-year reduction in duties beginning on September 1, 1985, and ending on January 1, 1995. The phaseout covered most of the significant products manufactured by the domestic bromine industry. For most of the high-profit brominated flame retardants, tariffs will remain for at least 5 years because they were among the products most affected by the agreement. Protected bromine chemicals included primarily brominated fire retardants such as tetrabromobisphenol-A, decabromodiphenyl oxide, and octabromodiphenyl oxide. A number of domestic producers of bromine compounds could be adversely impacted by unfair competition from imports from Israel. On June 13, 1985, an amendment to the Generalized System of Preferences (GSP), Executive Order 12519, provided separate import categories for selected bromine compounds, thereby allowing the Government to monitor imports. Ammonium bromide and calcium bromide were each given separate numbers for the Tariff Schedule of the United States (TSUS), and eight other brominated compounds collectively were given one number.[18] The U.S. Bromine Alliance composed of Dow, Ethyl, and Great Lakes had proposed a total exemption, alleging that a free-trade pact could cause the domestic industry damage because of the collateral effects of the phasedown of EDB as an additive in leaded gasoline. The alliance predicted imports of Israeli bromine products would rise from $9.7 million in 1983 to more than $40 million by the end of the decade. It claimed that the U.S. industry could not compete because of Israel's state-supported bromine industry, access to cheap raw materials, and Government-owned shipping.[19]

## WORLD REVIEW

The Pesticide Action Network (PAN), an international coalition of about 300 environmental and consumer groups, launched a worldwide campaign to put tighter controls on the export and labeling of pesticide products. PAN listed 12 pesticides, including DBCP as the greatest polluters.[20]

**Australia.**—The Australian Transport Advisory Council (ATAC), representing each State and the Commonwealth, recommended that unleaded gasoline be made available beginning July 1, 1985. ATAC also agreed that automobiles manufactured after January 1, 1986, and most other vehicles, after July 1, 1988, should be designed to run on unleaded gasoline. In New South Wales, compliance of all motor vehicles was to become compulsory on January 1, 1986. These decisions could adversely affect the use of EDB as a scavenger for lead in gasoline and decrease the demand for bromine.[21]

**Canada.**—Legislation that reduced the limit for leaded gasoline from 0.77 gram per liter (g/l) to 0.29 g/l beginning January 1, 1987, was expected to have the effect of decreasing the use of EDB as a lead scavenger by about 23% the first year.[22]

**China.**—A 1-million-pound-per-year bromine extraction unit began operation in October at the Laizhou Bromine Works, Jinan, Shandong. The unit was supplied with brines from wells in the area. Four additional units were scheduled for construction at the plant between 1986 and 1990.

**European Economic Community.**—The trend toward a lead-in-gasoline limit of 0.15 g/l continued to affect the consumption of bromine in Europe. At the beginning of the year, Austria, the Federal Republic of Germany, Norway, Sweden, and Switzerland were enforcing the 0.15-g/l limit for all leaded gasoline. In Denmark, the limit applied initially to regular gasoline only, but was extended to premium gasoline in July. Belgium, Finland, the Netherlands, and the United Kingdom planned to reduce lead limits to the same level in the near future, and the European Economic Community issued a proposal for a directive requiring all member states to enforce a maximum lead limit of 0.15 g/l by July 1, 1989.[23]

**Israel.**—Israel Chemicals Ltd. (ICL) was interested in selling a 26% share of the firm to offset an investment program. ICL also agreed, in principle, to issue shares of its Dead Sea Bromine Co. Ltd. (DBC) subsidiary on the American Stock Exchange to raise capital for major expansion projects. These projects included the Dead Sea Works Ltd.'s (DSW) planned expansion of potash production capacity, which would increase the supply of brines for production of bromine by 43%. Total investment was announced at nearly $1 billion and also included expanded chlorine production. Brines from the potash process, containing about 14,000 ppm bromine, were processed at a bromine plant at Sdom. DBC completed an expansion of bromine and bromine compounds production to 120,000 and 100,000 tons per year, respectively, and was actively developing markets for bromine compounds, such as fire retardants, agricultural chemicals, and oilfield chemicals. ICL announced record-high total earnings for the 1984-85 fiscal year, up nearly 50% to $56 million. The company was spared the economic effects of the declining market for EDB. Much of the increase was attributed to a move into downstream operations, including the bromine and bromine compounds operations of DBC. The effort was designed to increase the group's foreign sales rapidly from $381 million in 1984-85 to an annual level of more than $700 million. Exports of the group expanded by 15% in 1984 and were projected to double within 5 years. In addition, the complex also produced salt and magnesium oxide as byproducts. DSW was installing two plants to produce 300,000 tons per year of potassium sulfate as another byproduct.

**Table 4.—World bromine plant capacities and sources**

| Country and company | Location | Capacity (million pounds) | Source |
|---|---|---|---|
| China: | | | |
| Laizhou Bromine Works | Shandong | 1 | Underground brines. |
| France: | | | |
| Atochem | Port-de-Bouc | 30 | Seawater. |
| Mines de Potasse d'Alsace S.A | Mulhouse | 19 | Bitterns of mined potash production. |
| Germany, Federal Republic of: | | | |
| Kali und Salz AG: | | | |
| Bergmannssegen-Hugo Mines | Lehrte | 8 | Do. |
| Salzdetfurth Mine | Bad Salzdetfurth. | | |
| India: | | | |
| Hindustan Salts Ltd | Jaipur | 1.6 | Seawater bitterns from salt production. |
| Mettur Chemicals | Mettur Dam | | |
| Tata Chemicals | Mithapur | | |
| Israel: | | | |
| Dead Sea Bromine Co. Ltd | Sdom | 220 | Bitterns of potash production from surface brines. |
| Italy: | | | |
| Società Azionaria Industrial Bromo Italiana | Margherita di Savoia. | 2 | Seawater bitterns from salt production. |
| Japan: | | | |
| Asahi Glass Co. Ltd | Kitakyushu | 9 | Seawater bitterns. |
| Toyo Soda Manufacturing Co. Ltd | Nanyo | 26 | Do. |
| Spain: | | | |
| Derivados del Etilo S.A | Villaricos | 2 | Seawater. |
| U.S.S.R.: | | | |
| NA | NA | 150 | Well brines. |
| United Kingdom: | | | |
| Associated Octel Co. Ltd | Amlwch | 66 | Do. |

NA Not available.

**New Zealand.**—The Government planned to reduce the present lead limit in gasoline from 0.84 to 0.45 g/l at a future date. The implementation could result in decreased consumption of bromine by about 15% the first year.[24]

**U.S.S.R.**—A new complex to produce tetrabromobisphenol was planned at Nebit-Dag. Scientists of the Turkmen Academy of Sciences Institute of Chemistry researched ways to extract other coproducts from the bromine and iodine brines. The production of bromine and iodine at another plant was also to be expanded. The completion of the new plant and the expansion of existing halogen production capacity would make the complex the largest enterprise in the chemical sector.[25] Another iodine plant at Neftechala was to include ion-exchange equipment through which the product would cascade to processing equipment at a lower level, but footings for the equipment had been installed for only one level.[26]

**Table 5.—Bromine: World production, by country[1]**

(Thousand pounds)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| France[e] | 36,000 | [r]37,000 | [r]35,000 | [r]37,000 | 44,000 |
| Germany, Federal Republic of | 7,864 | 6,775 | 6,914 | 7,288 | 6,000 |
| India[e] | 770 | 770 | 770 | 770 | 770 |
| Israel[e] | [3]97,047 | 154,000 | 154,000 | 198,400 | 220,000 |
| Italy[e] | 1,320 | 1,320 | 1,100 | 1,100 | 1,320 |
| Japan[e] | 26,500 | 26,500 | 26,500 | 26,500 | 26,500 |
| Spain[e] | 900 | 800 | 700 | 660 | 800 |
| U.S.S.R.[e] | 150,000 | 150,000 | 150,000 | 154,000 | 154,000 |
| United Kingdom | 60,848 | 65,698 | 56,879 | 62,832 | 61,700 |
| United States[e] [4] | [3]377,097 | 401,100 | 370,000 | 385,000 | 320,000 |
| Total | 758,346 | [r]843,963 | 801,863 | 873,550 | 835,090 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Table includes data available through May 6, 1986.

[2]In addition to the countries listed, several other nations produce bromine, but output data are not reported, and available general information is inadequate for formulation of reliable estimates of output levels.

[3]Reported figure.

[4]Sold or used by producers.

## TECHNOLOGY

Great Lakes continued research on polycrystalline silicon manufacture using bromine. Polycrystalline silicon of ultrahigh-purity semiconductor grades (99.97% pure) is obtained by reduction of purified tetrachlorosilane or trichlorosilane with purified hydrogen. Bromosilanes could also be used in making polycrystalline silicon. J. C. Schumacher Co. announced plans to start a 75-ton-per-year pilot plant to produce bromosilanes using a bromine process.[27]

The stoichiometry and relative rate of bromochloramine oxidation of a substance in the presence of monochloramine were described. The results were important not only because the methods have been used to measure oxidants in the environment under conditions where bromochloramine may be present, but also because they were believed to be the first describing the reaction of bromochloramine with any substance.[28]

The U.S. Department of Energy (DOE) contracted with Exxon Research and Engineering Co. to produce a zinc-bromine battery that powered Ford's ETX electric test vehicle. This was the first advanced secondary battery to power an electric vehicle successfully. DOE also contracted with Energy Research Corp. to produce a 50-kilowatt-per-hour battery module that would be joined to supply a 500-kilowatt-per-hour stationary energy storage battery. After testing, a 100-megawatt-per-hour zinc-bromine battery could be used by utility companies to level their demand loads.[29]

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[1] Physical scientist, Division of Industrial Minerals.

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[5] ———. USDA Compiling Computerized Directory of Pesticide Groundwater Projects. V. 13, No. 42, 1985, p. 6.

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[11] Chemical Marketing Reporter. Chemical Profile. V. 227, No. 7, 1985, p. 54.

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[18] Federal Register. Presidential Documents. V. 50, No. 116, June 17, 1985, pp. 25037-25062.

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[20] Chemical Week. Pushing To Tighten Pesticide Exports. V. 136, No. 24, 1985, pp. 17-18.

[21] International Lead and Zinc Study Group (London). Lead in Gasoline, 1985. Feb. 1985, 14 pp.

[22] Work cited in footnote 21.

[23] Work cited in footnote 21.

[24] Work cited in footnote 21.

[25] Sarkisyan, K. Ashkhabad Turkmenskaya Iskra (in Russian), July 19, 1982, p. 4.

[26] Gopanyuk, S. Irresponsibility Slows Construction on Neftechala Iodobromite Plant. Baku Vyshka (in Russian), Apr. 10, 1982, p. 2.

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# Cadmium

## By Patricia A. Plunkert[1]

Domestic production of cadmium metal decreased only slightly in 1985, despite the closure of a domestic zinc refinery and its cadmium plant in April. A reduction in the total inventories of cadmium metal and cadmium compounds together with an increase in imported metal led to an increase in apparent consumption of cadmium. Canada continued as the principal source of imported cadmium. The price of cadmium metal declined, continuing a trend that began in mid-1984.

**Domestic Data Coverage.**—Domestic production data for cadmium metal and compounds are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the five metal-producing plants to which a survey request was sent, all responded, representing 100% of the total cadmium metal production shown in tables 1 and 5. Of the 11 operations that produced cadmium compounds to which a survey request was sent, all responded, representing 100% of the cadmium content of production of cadmium compounds shown in tables 3 and 4.

**Table 1.—Salient cadmium statistics**

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production[1] ---- metric tons-- | 1,603 | 1,007 | 1,052 | 1,686 | 1,603 |
| Shipments by producers[2] ---- do---- | 1,382 | 1,832 | 1,495 | 1,811 | 1,791 |
| Value ---- thousands-- | $3,838 | $2,628 | $1,786 | $2,581 | $2,436 |
| Exports ---- metric tons-- | 239 | 11 | 170 | 106 | 86 |
| Imports for consumption, metal ---- do---- | 3,090 | 2,305 | 2,196 | 1,889 | 1,988 |
| Apparent consumption ---- do---- | 4,378 | 3,728 | 3,763 | [r]3,300 | 3,720 |
| Price: Average per pound[3] ---- | $1.93 | $1.11 | $1.13 | $1.69 | $1.21 |
| World: Production ---- metric tons-- | [r]17,380 | [r]16,422 | 17,527 | [p]19,171 | [e]18,662 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Primary and secondary cadmium metal. Includes equivalent metal content of cadmium sponge used directly in production of compounds.

[2] Includes metal consumed at producer plants.

[3] Average quoted price for cadmium sticks and balls in lots of 1 to 5 tons.

**Legislation and Government Programs.**—On July 29, the Environmental Protection Agency (EPA) announced the availability of nine ambient water quality criteria documents that updated and revised previously published criteria. Cadmium is one of the nine substances for which revised criteria were published. The document detailed acceptable cadmium concentration levels for both freshwater and saltwater systems.[2]

On October 16, the EPA issued a notice of intent to list cadmium as a hazardous air pollutant and to establish emission standards under the Clean Air Act.[3]

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Public Law 96-510), commonly known as the Superfund, expired on September 30, 1985. Various reauthorization bills, such as S-51 passed by the Senate on September 26 and HR-2817 passed by the House of Representatives on December 10, were under consideration by the Congress.

On July 8, the White House announced that the President had approved the National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the National Defense Stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict that would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of materials already possessed by the Government. The status of cadmium was deferred until further detailed studies could be made. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, stated that no action may be taken before October 1, 1986, to implement or administer any change in a stockpile goal in effect on October 1, 1984, that results in a reduction in the quality or quantity of any strategic and critical material to be acquired for the National Defense Stockpile. Therefore, as of December 31, 1985, the National Defense Stockpile goal for cadmium metal remained at 5,307 metric tons, and the stockpile inventory was 2,871 tons of cadmium metal.

## DOMESTIC PRODUCTION

Domestic production of cadmium metal decreased slightly compared with that of 1984, despite the announced indefinite closure by ASARCO Incorporated in April 1985 of its zinc refinery and cadmium plant in Corpus Christi, TX. Prior to its closing, this facility was operating at approximately 50% of capacity. The production of cadmium compounds decreased significantly in 1985 with production levels at approximately two-thirds those of 1984.

Table 2.—Primary cadmium producers in the United States in 1985

| Company | Plant location |
|---|---|
| AMAX Inc | Sauget, IL. |
| ASARCO Incorporated | Corpus Christi, TX, and Denver, CO. |
| Jersey Minière Zinc Co | Clarksville, TN. |
| St. Joe Resources Co | Bartlesville, OK. |

Table 3.—U.S. production of cadmium compounds other than cadmium sulfide[1]

(Metric tons)

| Year | Quantity (cadmium content) |
|---|---|
| 1981 | 885 |
| 1982 | 971 |
| 1983 | 1,024 |
| 1984 | 1,510 |
| 1985 | 1,021 |

[1] Includes plating salts and oxide.

Table 4.—U.S. production of cadmium sulfide[1]

(Metric tons)

| Year | Quantity (cadmium content) |
|---|---|
| 1981 | 527 |
| 1982 | 374 |
| 1983 | 670 |
| 1984 | 771 |
| 1985 | 477 |

[1] Includes cadmium lithopone and cadmium sulfoselenide.

## CONSUMPTION AND USES

Apparent consumption of cadmium increased compared with that of 1984. Although the Bureau of Mines does not collect actual consumption data, apparent consumption by use categories was estimated as follows: coating and plating, 34%; batteries, 27%; pigments, 16%; plastic stabilizers, 15%; alloys and other uses, 8%.

Ferro Corp.'s Color Div. introduced a line of cadmium pigments, consisting of 16 pure pigments and 16 lithopones with color ranges from yellow to maroon. SCM Pigments, a division of SCM Corp., announced the development of a new line of cadmium pigments that the company reported were 10% to 25% stronger in tinting strength than conventional cadmium pigments.[4]

Varta Batteries Inc. announced the introduction of a rechargeable 1.2-volt button cell that it believed to be the thinnest nickel-cadmium battery ever developed and that it reported could be used to miniaturize a wide range of products.[5]

**Table 5.—Supply and apparent consumption of cadmium**

(Metric tons)

| | 1983 | 1984 | 1985 |
|---|---|---|---|
| Stocks, Jan. 1 | 1,417 | 732 | 901 |
| Production | 1,052 | 1,686 | 1,603 |
| Imports, metal | 2,196 | 1,889 | 1,988 |
| Total supply | 4,665 | 4,307 | 4,492 |
| Exports | 170 | 106 | 86 |
| Stocks, Dec. 31 | 732 | r901 | 686 |
| Apparent consumption[1] | 3,763 | r3,300 | 3,720 |

r Revised.

[1] Total supply minus exports and yearend stocks.

## STOCKS

Total inventories of cadmium in all forms decreased approximately 24% compared with those of 1984 and reached their lowest level in over 30 years. Stocks held by metal producers showed the sharpest decline owing in part to the closure of Asarco's Corpus Christi refinery.

**Table 6.—Industry stocks, December 31**

(Metric tons)

| | 1984 | | 1985 | |
|---|---|---|---|---|
| | Cadmium metal | Cadmium in compounds | Cadmium metal | Cadmium in compounds |
| Metal producers | 208 | W | 136 | W |
| Compound manufacturers | r91 | r548 | 111 | 377 |
| Distributors | 52 | 2 | 59 | 3 |
| Total | r351 | r550 | 306 | 380 |

r Revised. W Withheld to avoid disclosing company proprietary data; included with "Compound manufacturers."

## PRICES

At the beginning of 1985, AMAX Inc. published a domestic producer price of $1.55 per pound for cadmium metal whereas St. Joe Resources Co. National Zinc Div.'s published price was $1.25 per pound. Both price quotes remained at these levels through June. On July 2, AMAX lowered its price to $1.00 per pound, and on July 25, National Zinc also reduced its price to $1.00 per pound. Both published domestic producer prices for cadmium metal remained at $1.00 per pound through yearend.

Dealer prices in January were listed at $1.11 to $1.15 per pound for cadmium metal. These prices fluctuated during 1985 but trended downward to close the year at $0.77 to $0.83 per pound.

## FOREIGN TRADE

Exports of cadmium metal and cadmium in alloys, dross, flue dusts, residues, and scrap decreased compared with those of 1984. The four largest recipients in 1985, in descending order of receipts, France, Sweden, Netherlands, and Canada, received approximately 80% of U.S. cadmium exports.

Cadmium metal imports for consumption increased compared with those of 1984 but remained well below the average 2,400 tons of material imported during the previous 5-year period. The principal supplying country continued to be Canada, which provided over 50% of the total imports in 1985.

Imports of metal and flue dust from most favored nations (MFN) continued to be duty free. A statutory duty of $0.15 per pound continued to be imposed on cadmium metal imported from non-MFN.

**Table 7.—U.S. exports of cadmium metal and cadmium in alloys, dross, flue dust, residues, and scrap**

| Year | Quantity (metric tons) | Value (thousands) |
|---|---|---|
| 1983 | 170 | $351 |
| 1984 | 106 | 208 |
| 1985 | 86 | 342 |

Source: Bureau of the Census.

**Table 8.—U.S. imports for consumption[1] of cadmium metal, by country**

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Australia | 363 | $792 | 458 | $1,043 |
| Belgium-Luxembourg | ([2]) | 8 | 12 | 96 |
| Canada | [3]862 | 2,817 | 1,044 | 2,159 |
| Finland | 47 | 126 | 30 | 61 |
| France | [3]27 | 119 | 20 | 55 |
| Germany, Federal Republic of | 155 | 343 | 203 | 356 |
| Japan | ([2]) | 2 | -- | -- |
| Korea, Republic of | 84 | 191 | -- | -- |
| Mexico | 174 | 344 | 162 | 238 |
| Norway | 35 | 94 | -- | -- |
| Peru | 103 | 227 | 27 | 48 |
| Sweden | 10 | 25 | 6 | 15 |
| United Kingdom | 19 | 13 | -- | -- |
| Yugoslavia | 10 | 37 | 24 | 49 |
| Total[4] | [3]1,889 | 5,133 | 1,988 | 4,122 |

[1] General imports were as follows, in metric tons: 1984—1,898 and 1985—1,988.
[2] Less than 1/2 unit.
[3] Includes waste and scrap (gross weight).
[4] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

**Greece.**—Metra S.A., a subsidiary of the Government-owned Hellenic Industrial Development Bank, announced that it was granted the rights to develop a 2.6-million-ton sulfide ore deposit in the Molai District of Laconia. The ore contained lead and zinc with some cadmium, copper, and silver. The company reportedly planned to mine the deposit at the rate of 300,000 tons of ore per year for about 10 years.[6]

**Hong Kong.**—Sylva Industries Ltd., a wholly owned subsidiary of Gold Peak Industries, announced that it was the country's first manufacturer of button-type rechargeable nickel-cadmium batteries.[7]

**Switzerland.**—An evaluation of proposals restricting the use of cadmium in Switzerland was begun. Included in the proposals were a restriction on cadmium electroplating and the importation of most products containing cadmium-coated components, the enactment of regulations for the recovery of nickel-cadmium batteries, and the progressive reduction of the cadmium content in zinc used for galvanizing from 0.1% to 0.025% over the next 5 years. These proposals require Government approval before enactment.[8]

Discussions between the Swiss Government and the Swiss Plastics Industries Federation resulted in an agreement to restrict the annual consumption of cadmium in pigments and stabilizers to a maximum of 5 tons by 1988.[9]

## Table 9.—Cadmium: World production,[1] by country

(Metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria[e] | 65 | 65 | 50 | 50 | 50 |
| Argentina | -- | 21 | [e]19 | [e]20 | 20 |
| Australia (refined) | 1,031 | 1,010 | 1,104 | 1,049 | 1,000 |
| Austria | 55 | 48 | 46 | 49 | 50 |
| Belgium | 1,176 | 996 | 1,260 | 1,476 | 1,200 |
| Brazil | 45 | 73 | 189 | 225 | 225 |
| Bulgaria[e] | 210 | 200 | 200 | 200 | 200 |
| Canada (refined) | 1,298 | [r]854 | 1,456 | 1,602 | 1,400 |
| China[e] | 270 | 300 | 300 | 300 | 300 |
| Finland | 621 | 566 | 616 | 614 | 610 |
| France | 663 | [2]793 | 513 | 563 | 510 |
| German Democratic Republic[e] | 16 | 16 | [r]15 | [r]15 | 15 |
| Germany, Federal Republic of | 1,192 | 1,030 | 1,094 | 1,111 | 1,075 |
| India | 113 | 131 | 131 | 148 | [3]194 |
| Italy | [2]489 | [2]475 | 450 | 520 | 450 |
| Japan | 1,977 | 2,034 | 2,214 | 2,423 | 2,640 |
| Korea, North[e] | 140 | 100 | 100 | 100 | 100 |
| Korea, Republic of | 300 | 320 | 320 | 320 | 300 |
| Mexico (refined) | 590 | 607 | 642 | 571 | 600 |
| Namibia | -- | 110 | 51 | 40 | 30 |
| Netherlands | 518 | 497 | 513 | 636 | 600 |
| Norway | 117 | 104 | 117 | 150 | 150 |
| Peru | 307 | 421 | 451 | 390 | 420 |
| Poland | 580 | 570 | [e]570 | [e]570 | 600 |
| Romania[e] | 85 | 80 | 80 | [r]75 | 75 |
| Spain | 303 | 286 | 278 | 290 | 300 |
| U.S.S.R.[e] | 2,900 | 2,900 | 3,000 | 3,000 | 3,000 |
| United Kingdom | 278 | 354 | 340 | 390 | 375 |
| United States[2] | 1,603 | 1,007 | 1,052 | 1,686 | [3]1,603 |
| Yugoslavia | 208 | 174 | 48 | 270 | 250 |
| Zaire | [2]230 | [r]280 | 308 | 318 | 320 |
| Zambia | ([4]) | -- | -- | -- | -- |
| Total | [r]17,380 | [r]16,422 | 17,527 | 19,171 | 18,662 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] This table gives unwrought production from ores, concentrates, flue dusts, and other materials of both domestic and imported origin. Sources generally do not indicate if secondary metal (recovered from scrap) is included or not; where known, this has been indicated by footnote. Data derived in part from World Metal Statistics (published by World Bureau of Metal Statistics, London) and from Metal Statistics (published by Metallgesellschaft Aktiengesellschaft, Frankfurt am Main). Cadmium is found in ores, concentrates, and/or flue dusts in several other countries, but these materials are exported for treatment elsewhere to recover cadmium metal; therefore, such output is not reported in this table to avoid double counting. Table includes data available through Apr. 8, 1986.

[2] Includes secondary.

[3] Reported figure.

[4] Revised to zero.

## TECHNOLOGY

Researchers at the Corning Glass Works, Corning, NY, reported the discovery of a new cadmium-bearing fluoride glass system that was 10 times more resistant to water corrosion than zirconium-based fluoride glasses. The new glass, a mixture of cadmium, lithium, aluminum, and lead fluorides, was developed under an Air Force Office of Scientific Research contract aimed at seeking improved glass systems. The main practical advantage of the new glass was its higher resistance to water corrosion, which could lead to applications in infrared optics and optical windows.[10]

Boeing Aerospace Co. reported the development of thin film polycrystalline solar cells with energy conversion levels of nearly 12%, eclipsing a previous efficiency level of 9%. The cells were made of copper-indium diselenide/zinc-cadmium sulfide and were part of an effort to produce solar cells for large-scale terrestrial solar power applications and for potential uses in space.[11]

Researchers at Los Alamos National Laboratory in New Mexico reported the discovery of a peptide that protected plants from being poisoned by toxic metals. The unnamed compound, a chain of seven amino acids, reportedly bound cadmium and allowed plant cells to tolerate otherwise toxic concentrations of the metal. This discovery could lead to new methods of growing more nutritious crops and to the development of biochemical filters that remove toxic metals. The scientists speculated that the peptide might be used to scavenge metals from contaminated soil, sewage sludge, and waste effluent.[12]

Developments in cadmium technology during the year were abstracted in Cadmium Abstracts, a quarterly publication available through the Cadmium Association, 34 Berkeley Square, London W1X 6AJ, England.

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[1] Physical scientist, Division of Nonferrous Metals.

[2] Federal Register. Water Quality Criteria; Availability of Documents. V. 50, No. 145, July 29, 1985, pp. 30784-30796.

[3] ———. Assessment of Cadmium Under Section 122 of the Clean Air Act. V. 50, No. 200, Oct. 16, 1985, pp. 42000-42004.

[4] Gross, S. Tailor-Made Technology, Pin-Point Marketing and High-Yield Resins Spark Vigorous Growth. Chem. Week, v. 137, No. 24, Dec. 11, 1985, pp. SAS 3-SAS 46.

[5] Advanced Battery Technology. V. 21, No. 4, Apr. 1985, p. 6.

[6] Mining Journal (London). Greek Lead-Zinc Project. V. 304, No. 7816, June 7, 1985, p. 406.

[7] Advanced Battery Technology. V. 21, No. 12, Dec. 1985, p. 1.

[8] Metal Bulletin (London). Cutting Down on Cadmium. No. 7004, July 19, 1985, p. 10.

[9] Page 10 of work cited in footnote 8.

[10] Lasers & Applications. Corning Discovers New Fluoride Glass System. V. 4, No. 10, Oct. 1985, pp. 30, 32.

[11] Photonics Spectra. Boeing, Sovonics Boost Efficiency of Solar Cells. V. 19, Issue 12, Dec. 1985, p. 8.

[12] Chemical & Engineering News. Peptide Protects Plants From Cadmium. V. 63, No. 26, July 1, 1985, p. 22.

# Calcium and Calcium Compounds

**By Lawrence Pelham[1]**

Calcium, the fifth most abundant element in the Earth's crust, is very active, and occurs in nature in combination with other elements. The Bureau of Mines publishes individual reports for several of these calcium minerals and compounds. The commercial name for calcium fluoride is fluorspar; calcium carbonate is known as limestone; and calcium oxide and hydroxide are called lime. Information on these materials can be obtained in the "Fluorspar," "Crushed Stone," and "Lime" chapters of the "Minerals Yearbook." Other calcium compounds are covered in the chapter concerning the element with which it is combined; for example, calcium bromide is discussed in the"Bromine"chapter. This chapter covers calcium metal, calcium chloride, and various other calcium compounds not covered elsewhere.

Calcium metal was manufactured by one company in Connecticut. Natural calcium chloride was produced by three companies in California, two companies in Michigan, and one company in Washington. Synthetic calcium chloride was manufactured by one company in Louisiana, two companies in New York, and two companies in Washington.

**Domestic Data Coverage.**—Domestic production data for calcium chloride are developed by the Bureau of Mines from a voluntary survey of U.S. operations entitled "Calcium Chloride and Calcium-Magnesium Chloride." Of the 11 operations to which a survey request was sent, all responded, representing 100% of the total production shown in table 1.

## DOMESTIC PRODUCTION

Pfizer Inc. produced calcium metal at Canaan, CT, by the Pidgeon process—an aluminothermic process in which high-purity calcium oxide, produced by calcining limestone, and aluminum powder are briquetted and heated in vacuum retorts. The vaporized calcium metal product is collected as a "crown" in a water-cooled condenser. Pfizer accounted for an estimated 50% of total calcium metal production in market economy countries.

Pfizer produced commercial-grade calcium containing 98.5% calcium in seven shapes, high-purity redistilled metal containing 99.2% calcium in four shapes, and an 80% calcium-20% magnesium alloy. Pfizer also produced an alloy consisting of 25% calcium and 75% aluminum for use in maintenance free batteries and a pure calcium wire used in the steel industry to modify inclusions. Elkem Metal Co., a Norwegian-owned company with headquarters at Pittsburgh, PA, produced calcium alloys at its plant in Alloy, WV, including a calcium-silicon alloy containing about 30% calcium, 65% silicon, and 5% iron, and two proprietary alloys that contain barium, and barium and aluminum. The Foote Mineral Co. at Exton, PA, and ASARCO Incorporated at New York, NY, also produced calcium alloys. The Pesses Co. produced calcium alloys for use in the production of iron, steel, and nickel alloys.

National Chloride Co. of America, Cargill Inc.'s Leslie Salt Co., and Hill Bros. Chemical Co. produced calcium chloride from dry-lake brine wells in San Bernardino County, CA. Hill Bros. Chemical also produced from a second operation near Cadiz Lake. Total output in California was slightly less than that of 1984. Natural calcium chloride production in California was much less than in Michigan. The Dow Chemical Co. and Wilkinson Chemical Corp. recovered calcium chloride from brines in Lapeer, Mason, and Midland Counties, MI. Dow continued to phase out all brine operations at its 80-year-old plant in Midland, MI, and relocate its calcium chloride operations to Ludington, MI. The phaseout was planned to be completed by mid-1986. Tahoma Chemical Co. Inc., a new company, began producing calcium chloride in Washington in November.

Allied Chemical Corp. recovered synthetic calcium chloride as a byproduct of soda ash production at its Solvay plant near Syracuse, NY, and as a byproduct at its Baton Rouge, LA, plant using hydrochloric acid and limestone; Texas United Chemical Corp. produced calcium chloride from purchased hydrochloric acid and limestone at its plant near Lake Charles, LA; and Occidental Chemical Corp. manufactured calcium chloride at Tacoma, WA, using limestone and hydrochloric acid. Reichold Chemicals Inc. produced a small amount of synthetic calcium chloride as a byproduct of pentachlorophenol manufacture at Tacoma, WA, before closing the operation permanently in February.

At yearend Allied was in the process of closing its Solvay complex in Syracuse, NY. Allied was expanding its plant in Amherstbury, Ontario, Canada, in order to continue serving calcium chloride customers in the Northeastern United States. Texas United Chemical announced plans to build a new granular calcium chloride plant in Lake Charles, LA, with an annual capacity of at least 20,000 short tons of a dry form of 94% to 97% calcium chloride. Construction had begun and completion was expected in May 1986.[2]

Calcium hypochlorite was produced by two U.S. companies: Olin Corp. and PPG Industries Inc. Total U.S. capacity for producing calcium hypochlorite was 116,500 tons per year.

Table 1.—U.S. production of calcium chloride (75% $CaCl_2$ equivalent)

| Year | Natural |  | Synthetic |  | Total |  |
|---|---|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1981 | 704,691 | $61,692 | 212,299 | $27,086 | 916,990 | $88,778 |
| 1982 | 616,513 | 61,483 | 236,894 | 31,279 | 853,407 | 92,762 |
| 1983 | 663,949 | 71,330 | 192,688 | 29,727 | 856,637 | 101,057 |
| 1984[e] | 838,000 | 93,000 | 198,000 | 31,500 | 1,036,000 | 124,500 |
| 1985 | W | W | W | W | 801,000 | 92,200 |

[e] Estimated. W Withheld to avoid disclosing company proprietary data.

## CONSUMPTION AND USES

Calcium metal was used in the manufacture of batteries, as an aid in removing bismuth in lead refining, as a desulfurizer and deoxidizer in steel refining, and as a reducing agent to recover refractory metals such as chromium, thorium, and rare earths from their oxides. Some minor uses were in the preparation of vitamin B and chelated calcium supplements, and as a cathode coating in some types of photoelectric tubes. The nuclear applications of calcium metal give it strategic significance; foreign sales must be approved by the U.S. Department of State. State Department approval had been denied to countries that were not a signatory of the United Nations Nuclear Nonproliferation Treaty.

Calcium chloride was used for road and pavement deicing, dust control and road base stabilization, coal and other bulk material thawing, oil and gas drilling, concrete-set acceleration, tire ballasting, and miscellaneous uses.

The principal use of calcium chloride was to melt snow and ice from roads, streets, bridges, and pavements. Calcium chloride is more effective at lower temperatures than rock salt and has been used mainly in the Northern and Eastern States. Because of its considerably higher price, it was used in conjunction with rock salt for maximum effectiveness and economy.

Calcium hypochlorite was used to disinfect swimming pools, which accounted for

85% of domestic demand, and in other municipal and industrial bleaching and sanitation processes. It was used as an algicide, bactericide, deodorant, water purifier, disinfectant, fungicide, and bleaching agent.

Calcium nitrate was used as a concrete additive to inhibit corrosion of steel reinforcement bars, accelerate setting time, and enhance strength.

Calcium carbide and calcium-silicon alloy were used to remove sulfur from molten pig iron as it was carried in transfer ladles from the blast furnace to the steelmaking furnace.

## PRICES AND SPECIFICATIONS

The published price of calcium metal crowns in quantities greater than 20,000 pounds increased on January 1 to $3.76 per ton and again on November 1 to $3.92. The price of calcium-silicon alloy remained unchanged. Yearend published prices and specifications were as follows:

| | Value per pound | |
|---|---|---|
| | 1984 | 1985 |
| Calcium metal, 1-ton lots, 50-pound full crowns, 10 by 18 inches, Ca + Mg 99.5%, Mg 0.7% | $3.25 | $3.92 |
| Calcium-silicon alloy, 32% calcium, carload lots, f.o.b. shipping point | .72 | .72 |

Source: Metals Week. V. 55, No. 53, 1984, p. 5; Metals Week. V. 56, No. 52, 1985, p. 5.

Calcium metal was usually sold in the form of crowns, broken crown pieces or nodules, or billets, which are produced by melting crowns in an argon atmosphere. The metal purity in these forms was at least 98%. Higher purity metal was obtained by redistillation.

Calcium metal was usually shipped in polyethylene bags under argon in an airtight 55-gallon steel drum.

Calcium chloride was sold as flake or pellet averaging about 75% $CaCl_2$, or as a liquid concentrate averaging 40% $CaCl_2$. Prices remained unchanged from those of 1984. Yearend 1985 published prices and specifications were as follows:

| | Value per ton |
|---|---|
| Calcium chloride concentrate, regular grade, 77% to 80%, flake, bulk, carload, works | $153.00 |
| 100-pound bags, carload, same basis | 196.00 |
| Anhydrous, 94% to 97%, flake or pellet, bulk, carload, same basis | 217.00 |
| 80-pound bags, carload, same basis | 279.00 |
| Brining grade, 80-pound bags | 285.00 |
| Calcium chloride liquid, 100% basis, tank car, tank truck, barge | 90.69 |
| 45%, same basis | 108.00 |
| Calcium chloride, United States Pharmacopoeia, granular, 225-pound drums, truckload, freight equalized | 1,800.00 |

Source: Chemical Marketing Reporter. V. 228, No. 27, 1985, p. 25.

## FOREIGN TRADE

Calcium chloride was exported to 37 countries. A significant decrease in calcium chloride exports occurred primarily because of the phasing out of Allied's Syracuse, NY, plant and Dow's Midland, MI, plant. Exports of calcium phosphates were 58,600 tons valued at $43 million compared with 40,000 tons valued at about $33 million in 1984. The leading destinations, in descending order, were Venezuela, Colombia, Canada, and Mexico, with material sent to a total of 52 countries.

Exports of other calcium compounds, including precipitated calcium carbonate, totaled 49,000 tons valued at $25 million compared with 37,000 tons valued at $17 million in 1984. Material in this category was sent to 57 countries. The leading destinations, in descending order, were the United Kingdom, the Netherlands, Mexico, Belgium, and Canada.

Calcium chloride imports increased significantly with large gains by Canada and Sweden. The increase by Canada was a direct result of planned expansion by Allied at its Amherstburg plant in conjunction with decreasing U.S. capacity. Crude calcium chloride imports increased 246% to 75,381 tons valued at $9.1 million, mainly from Canada. Other calcium chloride imports, which increased 747% to 2,355 tons valued at $1.9 million, were supplied almost equally by Brazil, Canada, the Federal Republic of Germany, and Sweden.

Imports of other calcium compounds included 15,800 tons of calcium carbide valued at $5.0 million from Canada; 3,700 tons of calcium hypochlorite valued at $5.1 million from Japan; 274,000 tons of crude calcium carbonate chalk valued at $1.7 million from the Bahamas; 7,300 tons of calcium carbonate chalk whiting valued at $1.6 million, mainly from France; 12,000 tons of precipitated calcium carbonate valued at $4.9 million, primarily from, in descending order, the United Kingdom, Japan, and France; and 139,000 tons of calcium nitrate valued at $14.6 million, mainly from Norway.

The U.S. International Trade Commission determined on March 28, under section 735(b) of the Tariff Act of 1930, that the domestic industry had been materially injured by reason of imports of calcium hypochlorite from Japan being sold at less than fair value. An antidumping order was issued by the U.S. Department of Commerce.

Calcium metal was imported from four countries. China supplied 249,913 pounds; France, 113,885 pounds; the U.S.S.R., 101,575 pounds; and Canada, 26,871 pounds. U.S. import duties in effect during the year for calcium metal were 3.6% ad valorem for countries having most-favored-nation status, 3.0% ad valorem for less developed and developing countries, and 25% ad valorem for non-most-favored nations.

Table 2.—U.S. exports of calcium chloride, by country

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Short tons | Value | Short tons | Value |
| Brazil | 209 | $67,916 | 70 | $22,483 |
| Cameroon | 885 | 277,159 | 1,333 | 179,239 |
| Canada | 20,976 | 2,658,345 | 14,755 | 2,494,945 |
| Egypt | 816 | 7,086,176 | 1,872 | 522,866 |
| Mexico | 295 | 113,470 | 786 | 216,595 |
| Netherlands | 2,340 | 7,634,897 | 874 | 138,583 |
| Norway | 1,453 | 344,531 | -- | -- |
| Saudi Arabia | 27 | 29,098 | 2 | 2,244 |
| Sweden | 1,541 | 752,141 | 968 | 1,136,964 |
| Trinidad and Tobago | 895 | 323,492 | 214 | 48,565 |
| United Arab Emirates | 2,364 | 377,780 | 2,713 | 636,939 |
| United Kingdom | 606 | 203,065 | 288 | 87,003 |
| Venezuela | 474 | 221,441 | 73 | 58,690 |
| Other | 1,181 | 478,150 | 2,195 | 797,840 |
| Total | 34,062 | 20,567,661 | 26,143 | 6,342,956 |

Source: Bureau of the Census.

Table 3.—U.S. imports for consumption of calcium and calcium chloride

| Year | Calcium |  | Calcium chloride |  |
|---|---|---|---|---|
|  | Pounds | Value[1] | Short tons | Value[1] |
| 1981 | 235,436 | $751,456 | 86,865 | $4,088,361 |
| 1982 | 333,054 | 966,665 | 60,623 | 3,010,212 |
| 1983 | 332,834 | 866,409 | 13,784 | 1,317,016 |
| 1984 | 248,973 | 669,586 | 22,078 | 1,816,915 |
| 1985 | 492,244 | 1,395,198 | 77,736 | 10,967,328 |

[1] U.S. Customs, insurance, freight.

Source: Bureau of the Census.

Table 4.—U.S. imports for consumption of calcium chloride, by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Short tons | Value[1] | Short tons | Value[1] |
| Canada | 18,320 | $1,188,591 | 65,458 | $7,272,298 |
| Germany, Federal Republic of | 87 | 246,331 | 621 | 327,445 |
| Mexico | 2,424 | 69,753 | 1,572 | 54,489 |
| Sweden | 1,214 | 261,761 | 9,279 | 2,411,923 |
| Other | 33 | 50,479 | 806 | 901,173 |
| Total | 22,078 | 1,816,915 | 77,736 | 10,967,328 |

[1] U.S. Customs, insurance, freight.

Source: Bureau of the Census.

## WORLD REVIEW

Calcium metal was produced in Canada, China, France, Japan, and the U.S.S.R., in addition to the United States. The market economy country production of calcium metal was estimated to be about 1,500 tons. Total world production was an estimated 2,000 tons.

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[1] Physical scientist, Division of Industrial Minerals.

[2] Chemical Marketing Reporter. V. 228, No. 22, 1985, p. 31.

# Cement

## By Wilton Johnson[1]

U.S. cement demand increased for the third consecutive year, reflecting continued growth in the construction industry. U.S. cement production remained essentially unchanged. According to the U.S. Department of Commerce, the value of new construction put in place increased 10% to $343 billion. Housing starts remained essentially unchanged at 1.74 million units. Public buildings, highways and streets, and other public construction accounted for the bulk of construction activity.

Imports increased 64% to 14.5 million short tons, the highest level in recorded U.S. history. Clinker imports were 32% of the total.

Shipments of portland and masonry cement from U.S. plants, excluding Puerto Rico, increased 4% to 83 million tons. All consuming regions except the South experienced gains in cement shipments. The Northeast region experienced the largest gain with 12%, followed by the West, 7%, and the North Central, 3%.

Acquisition of U.S. cement plants by foreign firms continued. By yearend, approximately 32% of clinker and 35% of finish grinding capacity had been acquired by foreign interests.

**Domestic Data Coverage.**—Domestic production and consumption data for cement are developed by means of the portland and masonry cement voluntary survey. Of the 144 cement manufacturing plants to which an annual survey collection request was made, 100% responded, representing 100% of the cement production and consumption data shown in table 1.

**Table 1.—Salient cement statistics**

(Thousand short tons unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States:[1] | | | | | |
| Production[2] | 71,710 | 63,355 | 70,420 | 77,700 | 77,895 |
| Shipments from mills[2] [3] | 71,748 | 64,066 | 70,933 | 80,166 | 83,032 |
| Value[2] [3] [4] thousands | $3,723,096 | $3,263,585 | $3,534,824 | $4,152,258 | $4,286,899 |
| Average value per ton[2] [3] [4] | $51.89 | $50.94 | $49.95 | $51.80 | $51.61 |
| Stocks at mills,[3] Dec. 31 | 7,372 | 6,758 | 6,711 | 6,866 | 7,282 |
| Exports | 300 | 201 | 118 | 80 | 98 |
| Imports for consumption | 3,963 | 2,911 | 4,221 | 8,689 | 14,120 |
| Consumption, apparent[5] [6] | 73,321 | 65,623 | 73,435 | 84,318 | 87,456 |
| World: Production | [r]977,384 | [r]978,362 | 1,010,116 | [p]1,045,468 | [e]1,071,225 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Excludes Puerto Rico and the Virgin Islands.

[2]Portland and masonry cement only.

[3]Includes imported cement shipped by domestic producers.

[4]Value received, f.o.b. mill, excluding cost of containers.

[5]Quantity shipped, plus imports, minus exports.

[6]Adjusted to eliminate duplication of imported clinker and cement shipped by domestic cement manufacturers.

## DOMESTIC PRODUCTION

One State agency and 48 companies operated 144 plants in 40 States. In addition, two companies operated two plants in Puerto Rico manufacturing hydraulic cement.

Some of the data are arranged by State or by groups of States that form cement districts. A cement district may represent a group of States or a portion of a State. The States of California, Illinois, New York, Pennsylvania, and Texas are divided to provide more definitive marketing information. Divisions for these States are as follows:

*California, Northern.*—Points north and west of the northern borders of Kern and San Luis Obispo Counties and the western borders of Inyo and Mono Counties.

*California, Southern.*—All other counties in California.

*Chicago, Metropolitan.*—The seven Illinois counties of Cook, Du Page, Kane, Kendall, Lake, McHenry, and Will.

*Illinois.*—All other counties in Illinois.

*New York, Western.*—All counties west of a dividing line following the eastern boundaries of Broome, Chenango, Lewis, Madison, Oneida, and St. Lawrence Counties.

*New York, Eastern.*—All counties east of the above dividing line, except Metropolitan New York.

*New York, Metropolitan.*—The five counties of New York City (Bronx, Kings, New York, Queens, and Richmond) plus Nassau, Rockland, Suffolk, and Westchester Counties.

*Pennsylvania, Eastern.*—All counties east of the eastern boundaries of Centre, Clinton, Franklin, Huntingdon, and Potter Counties.

*Pennsylvania, Western.*—All other counties in Pennsylvania.

*Texas, Northern.*—All counties north of a dividing line following the northern borders of Brazos, Burnet, Crockett, Jasper, Jeff Davis, Llano, Madison, Mason, Menard, Milam, Newton, Pecos, Polk, Robertson, San Jacinto, Schleicher, Tyler, Walker, and Williamson Counties.

*Texas, Southern.*—All counties south of the above dividing line.

### PORTLAND CEMENT

Clinker production in the United States, excluding Puerto Rico, decreased 4% to 66.3 million tons, and clinker imports received by U.S. cement producers increased 105% to 3.9 million tons. A total of 74.6 million tons of portland cement was ground in the United States. Stocks at mills increased by 380,000 tons to 6.8 million tons at yearend.

**Production Capacity.**—By yearend, multiplant operations were being run by 25 companies. The size of individual companies, as a percentage of total U.S. clinker production capacity, ranged from 0.3% to 10.6%. The 5 largest producers provided 34% of total clinker production; the 10 largest producers provided a combined total of 55%. The 10 largest companies, in terms of clinker production, were Lone Star Industries Inc., General Portland Inc., Lehigh Portland Cement Co., Gifford-Hill & Co. Inc., Southwestern Portland Cement Co., Dundee Cement Co., Blue Circle Inc., Ideal Basic Industries Inc., Kaiser Cement Corp., and Moore McCormack Resources Inc.

At yearend, 266 kilns at 124 plants were being operated by 45 companies and 1 State agency in the United States, excluding Puerto Rico. Annual clinker production capacity at yearend was 86.3 million tons. An average of 46 days downtime was reported for kiln maintenance and repair. The industry operated at an average 77% of its apparent capacity. Average annual clinker capacity of U.S. kilns was 325,000 tons, average plant capacity was 696,000 tons, and average company capacity was about 1.9 million tons. Three plants produced white cement. In addition, 11 plants operated grinding mills using only imported or purchased clinker, or interplant transfers of clinker. Of these, seven produced portland cement only, and four ground clinker for both masonry and portland cement. Based on the fineness to which Types I and II cements must be ground and allowing for downtime for maintenance, the U.S. cement industry's estimated annual grinding capacity was 102 million tons.

Clinker was produced by wet-process kilns at 53 plants (includes Puerto Rico) and by dry-process kilns at 68 plants; 5 additional plants operated both wet and dry kilns. The initiation of major plant modernization and expansion projects, including the installation of dry-process kilns and preheater-precalciner systems, continued to decline. At yearend, there were 59 suspension and 18 grate preheaters in operation.

**Capacity Additions Planned.**—Box-Crow Cement Co., formerly Dal-Tex Cement Corp., continued construction of a 1-million-ton-per-year cement plant near Midlothian, TX. The plant, which will be equipped with a coal-fired preheater-precalciner system, was expected to go on-stream in December 1986.

Florida Crushed Stone Co. began construction of its 600,000-ton-per-year cement plant in Brooksville, FL. The plant also will feature a 125-megawatt power generation facility and the capacity to produce 350,000 tons per year of lime. The cement portion of the plant was expected to go into production in November 1986. The power generation and lime facilities were expected to begin operation the first part of 1987.

**Plant Closings.**—General Portland closed the final kiln at its Tampa, FL, cement plant and signed a clinker supply contract with Mexico's Cementos Apasco S.A. to replace clinker production at the plant. The plant will be used exclusively for grinding Mexican clinker into finished portland cement.

Genstar Cement and Lime Co.'s San Andreas, CA, plant remained closed throughout the year.

Centex Corp.'s Corpus Christi, TX, plant closed and was used as a cement distribution terminal.

**Corporate Changes.**—Allentown Cement Co. Inc., headquartered in King of Prussia, PA, acquired National Gypsum Co.'s Evansville, PA, cement plant and distribution terminals at Bowie, MD, and Jersey City, NJ.

Ash Grove Cement Co. of Overland Park, KS, purchased Arkansas Cement Corp.'s Foreman, AR, cement plant and distribution terminals at Little Rock and Ft. Smith, AR; Shreveport and Alexandria, LA; and Oklahoma City, OK.

Blue Circle Industries PLC, a large British cement company, acquired Atlantic Cement Co.'s 1.5-million-ton-per-year portland cement plant at Ravena, NY, its 80,000-ton-per-year slag cement plant at Sparrows Point, MD, several distribution terminals along the east coast, and a fleet of cement-carrying barges.

Columbia Northwest Corp., a subsidiary of Ashland Oil Inc., sold its Bellingham, WA, plant and distribution terminals in Anchorage, AK, Portland, OR, and Pasco and Seattle, WA, to SME Cement Inc. of Bessemer, PA.

Independent Cement Co. purchased Lone Star Industries' Hagerstown, MD, plant and Baltimore distribution terminal.

Kaiser Cement sold its Hawaiian cement plant and distribution facilities to a new partnership formed by Lone Star Industries and the Australian firm Adelaide Brighton Cement Holdings Ltd.

**Table 2.—Portland cement production, capacity, and stocks in the United States, by district[1]**

| District | 1984 | | | | | 1985 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Plants active during year | Production[2] (thousand short tons) | Capacity[3] | | Stocks[4] at mills, Dec. 31 (thousand short tons) | Plants active during year | Production[2] (thousand short tons) | Capacity[3] | | Stocks[4] at mills, Dec. 31 (thousand short tons) |
| | | | Finish grinding (thousand short tons) | Percent utilized | | | | Finish grinding (thousand short tons) | Percent utilized | |
| New York and Maine | 6 | 3,198 | 4,199 | 76.2 | 248 | 6 | 3,655 | 3,915 | 93.3 | 304 |
| Pennsylvania, eastern | 9 | 4,476 | 5,102 | 87.7 | 371 | 9 | 4,327 | 5,121 | 84.5 | 360 |
| Pennsylvania, western | 4 | 1,338 | 2,441 | 54.8 | 131 | 4 | 1,272 | 2,466 | 51.5 | 169 |
| Maryland, Virginia, West Virginia | 5 | 3,307 | 3,880 | 85.2 | 255 | 5 | 3,453 | 3,882 | 88.9 | 329 |
| Ohio | 6 | 1,508 | 2,603 | 57.9 | 245 | 6 | 1,738 | 2,603 | 66.7 | 213 |
| Michigan and Wisconsin | 8 | 5,006 | 7,375 | 67.9 | 512 | 7 | 4,602 | 7,075 | 65.0 | 486 |
| Indiana and Kentucky | 5 | 2,772 | 3,845 | 72.1 | 291 | 5 | 2,672 | 3,733 | 71.5 | 308 |
| Illinois | 4 | 1,876 | 2,640 | 71.1 | 119 | 4 | 2,073 | 2,880 | 71.9 | 128 |
| Georgia and Tennessee | 4 | 2,013 | 2,483 | 81.1 | 144 | 4 | 2,021 | 2,495 | 81.0 | 227 |
| South Carolina | 3 | 2,313 | 3,400 | 68.0 | 146 | 3 | 2,276 | 3,447 | 66.0 | 97 |
| Florida | 6 | 3,268 | 4,258 | 76.7 | 199 | 5 | 3,403 | 4,186 | 81.3 | 178 |
| Alabama | 6 | 3,678 | 5,523 | 66.6 | 390 | 6 | 3,723 | 5,594 | 66.5 | 378 |
| Arkansas, Louisiana, Mississippi | 4 | 2,375 | 2,790 | 85.1 | 133 | 4 | 2,141 | 2,790 | 76.7 | 141 |
| South Dakota | 1 | 618 | 1,806 | 34.2 | 50 | 1 | 665 | 1,806 | 36.8 | 60 |
| Iowa | 4 | 1,763 | 3,001 | 58.7 | 347 | 4 | 1,642 | 3,072 | 53.4 | 348 |
| Missouri | 5 | 3,979 | 4,950 | 80.4 | 384 | 5 | 3,883 | 4,950 | 78.4 | 605 |
| Kansas and Nebraska | 7 | 2,654 | 4,019 | 66.0 | 319 | 7 | 2,684 | 4,072 | 65.9 | 408 |
| Oklahoma | 3 | 1,784 | 2,080 | 85.8 | 217 | 3 | 1,584 | 2,080 | 76.1 | 207 |
| Texas, northern | 9 | 5,044 | 5,489 | 91.9 | 353 | 9 | 5,096 | 5,474 | 93.0 | 364 |
| Texas, southern | 9 | 5,277 | 6,870 | 76.8 | 256 | 9 | 5,023 | 6,936 | 72.4 | 225 |
| Idaho, Montana, Utah | 6 | 1,754 | 2,365 | 74.2 | 234 | 6 | 1,744 | 2,315 | 75.3 | 300 |
| Colorado and Wyoming | 4 | 1,767 | 2,700 | 65.4 | 134 | 4 | 1,592 | 2,550 | 62.4 | 154 |
| Alaska, Oregon, Washington | 6 | 1,655 | 2,800 | 59.1 | 233 | 6 | 1,680 | 2,754 | 61.0 | 239 |
| Arizona, Nevada, New Mexico | 4 | 2,088 | 3,095 | 67.5 | 109 | 4 | 2,102 | 3,015 | 69.7 | 103 |
| California, northern | 3 | 2,518 | 3,937 | 64.0 | 235 | 3 | 2,518 | 3,165 | 79.5 | 119 |
| California, southern | 8 | 6,204 | 9,396 | 66.0 | 307 | 8 | 6,860 | 9,346 | 73.4 | 301 |
| Hawaii | 2 | 181 | 560 | 32.3 | 34 | 2 | 209 | 560 | 37.2 | 25 |
| **Total or average** | **141** | **74,414** | **103,607** | **71.8** | **6,396** | **139** | **[5]74,637** | **102,282** | **73.0** | **6,776** |
| **Puerto Rico** | **2** | **999** | **2,210** | **45.2** | **33** | **2** | **964** | **2,210** | **43.6** | **35** |

[1] Includes Puerto Rico. Includes data for three white cement facilities as follows: California (1), Pennsylvania (1), and Texas (1). Includes data for grinding plants (11 in 1984 and 1985) as follows: Alaska (1); Florida (1 in 1984 and 2 in 1985), Michigan (2 in 1984 and 1 in 1985), New York (1), Pennsylvania (2 in 1984 and 1 in 1985), Texas (2 in 1984 and 3 in 1985), and Wisconsin (2).

[2] Includes cement produced from imported clinker (1984—1,988,000 tons; 1985—1,914,000 tons).

[3] Grinding capacity based on fineness necessary to grind Types I and II cement, making allowance for downtime required for maintenance.

[4] Includes imported cement. Source of imports withheld to avoid disclosing company proprietary data.

[5] Data do not add to total shown because of independent rounding.

### Table 3.—Clinker capacity and production in the United States,[1] by district, as of December 31, 1985

| District | Active plants: Process used: Wet | Active plants: Process used: Dry | Active plants: Process used: Both | Active plants: Total | Number of kilns | Daily capacity (thousand short tons) | Average number of days for maintenance | Apparent annual capacity[2] (thousand short tons) | Production[3] (thousand short tons) | Percent utilized |
|---|---|---|---|---|---|---|---|---|---|---|
| New York and Maine | 4 | 2 | -- | 6 | 6 | 12.0 | 29 | 4,380 | 3,669 | 83.7 |
| Pennsylvania, eastern | 2 | 5 | -- | 7 | 16 | 15.0 | 41 | 3,894 | 3,461 | 88.8 |
| Pennsylvania, western | 3 | 1 | -- | 4 | 8 | 12.0 | 29 | 2,020 | 1,406 | 69.6 |
| Maryland, Virginia, West Virginia | 2 | 2 | -- | 4 | 15 | 6.0 | 48 | 3,812 | 3,426 | 89.8 |
| Ohio | 2 | 3 | 1 | 6 | 11 | 12.0 | 32 | 1,998 | 1,776 | 88.8 |
| Michigan and Wisconsin | 2 | 3 | -- | 5 | 13 | 17.0 | 41 | 5,522 | 3,703 | 67.0 |
| Indiana and Kentucky | 2 | 3 | -- | 5 | 10 | 12.0 | 47 | 3,824 | 2,644 | 69.1 |
| Illinois | -- | 4 | -- | 4 | 8 | 8.0 | 23 | 2,740 | 1,798 | 65.6 |
| Georgia and Tennessee | 1 | 2 | 1 | 4 | 7 | 7.0 | 38 | 2,291 | 2,010 | 87.7 |
| South Carolina | 1 | 1 | -- | 2 | 7 | 5.0 | 11 | 1,771 | 1,696 | 95.7 |
| Florida | 4 | 1 | -- | 5 | 7 | 9.0 | 48 | 2,857 | 2,344 | 82.0 |
| Alabama | 1 | 5 | -- | 6 | 8 | 14.0 | 29 | 4,705 | 2,685 | 57.0 |
| Arkansas, Louisiana, Mississippi | 3 | -- | -- | 3 | 8 | 8.0 | 40 | 2,603 | 2,055 | 78.9 |
| South Dakota | -- | -- | 1 | 1 | 4 | 3.0 | 72 | 880 | 667 | 75.7 |
| Iowa | 1 | 3 | -- | 4 | 8 | 9.0 | 51 | 2,826 | 1,643 | 58.1 |
| Missouri | 2 | 2 | -- | 4 | 7 | 14.0 | 39 | 4,566 | 4,086 | 89.4 |
| Kansas and Nebraska | 4 | 3 | -- | 7 | 19 | 10.0 | 38 | 3,273 | 2,631 | 80.3 |
| Oklahoma | 1 | 1 | -- | 2 | 7 | 5.0 | 6 | 1,795 | 1,585 | 88.3 |
| Texas, northern | 5 | 4 | -- | 9 | 24 | 15.0 | 29 | 5,051 | 4,555 | 90.1 |
| Texas, southern | 1 | 4 | 1 | 6 | 8 | 12.0 | 33 | 3,989 | 3,053 | 76.5 |
| Idaho, Montana, Utah | 4 | 1 | -- | 5 | 10 | 7.0 | 45 | 2,244 | 1,730 | 77.0 |
| Colorado and Wyoming | 2 | 2 | -- | 4 | 7 | 7.0 | 49 | 2,218 | 1,631 | 73.5 |
| Alaska, Oregon, Washington | 3 | 2 | -- | 5 | 8 | 5.0 | 13 | 1,762 | 1,336 | 75.8 |
| Arizona, Nevada, New Mexico | -- | 4 | -- | 4 | 11 | 8.0 | 44 | 2,572 | 1,954 | 75.9 |
| California, northern | -- | 3 | -- | 3 | 3 | 9.0 | 31 | 3,008 | 2,426 | 80.6 |
| California, southern | 1 | 6 | 1 | 8 | 24 | 28.0 | 39 | 9,135 | 6,136 | 67.1 |
| Hawaii | -- | 1 | -- | 1 | 2 | 2.0 | 66 | 599 | 201 | 33.5 |
| Total or average | 51 | 68 | 5 | 124 | 266 | 271.0 | 46 | 86,335 | 66,307 | 76.8 |
| Puerto Rico | 2 | -- | -- | 2 | 9 | 7.0 | 16 | 2,449 | 869 | 35.4 |

[1] Includes Puerto Rico and white cement producing facilities.

[2] Calculated on individual company data; 365 days, minus average days for maintenance, times the reported 24-hour capacity.

[3] Includes production reported for plants that added or shut down kilns during the year.

### Table 4.—Daily clinker capacity in the United States,[1] December 31

| Short tons per 24-hour period | Number | | Total capacity (short tons) | Percent of total capacity |
|---|---|---|---|---|
| | Plants | Kilns[2] | | |
| 1984: | | | | |
| Less than 1,150 | 25 | 44 | 21,334 | 7.5 |
| 1,151 to 1,700 | 28 | 47 | 38,708 | 13.7 |
| 1,701 to 2,300 | 29 | 55 | 55,077 | 19.4 |
| 2,301 to 3,300 | 22 | 47 | 54,797 | 19.3 |
| 3,301 and over | 28 | 88 | 113,532 | 40.1 |
| Total | 132 | 281 | 283,448 | 100.0 |
| 1985: | | | | |
| Less than 1,150 | 25 | 41 | 19,457 | 7.0 |
| 1,151 to 1,700 | 27 | 58 | 45,283 | 16.3 |
| 1,701 to 2,300 | 24 | 43 | 44,745 | 16.1 |
| 2,301 to 3,300 | 22 | 49 | 52,596 | 19.0 |
| 3,301 and over | 28 | 84 | 116,239 | 41.8 |
| Total | 126 | 275 | 278,320 | 100.0 |

[1] Includes Puerto Rico and white cement producing facilities.
[2] Total number in operation at plants.

### Table 5.—Raw materials used in producing portland cement in the United States[1]

(Thousand short tons)

| Raw materials | 1983 | 1984 | 1985 |
|---|---|---|---|
| Calcareous: | | | |
| Limestone (includes aragonite, marble, chalk) | 73,075 | 78,484 | 77,627 |
| Cement rock (includes marl) | 21,644 | 27,010 | 24,255 |
| Coral | 2,030 | 1,103 | 1,277 |
| Other | | | 243 |
| Argillaceous: | | | |
| Clay | 5,736 | 6,045 | 5,635 |
| Shale | 3,011 | 3,067 | 3,182 |
| Other (includes staurolite, bauxite, aluminum dross, alumina, volcanic material, other) | 118 | 47 | 123 |
| Siliceous: | | | |
| Sand and calcium silicate | 1,669 | 1,958 | 1,930 |
| Sandstone, quartzite, other | 691 | 696 | 608 |
| Ferrous: Iron ore, pyrites, millscale, other iron-bearing material | 1,058 | 1,282 | 1,307 |
| Other: | | | |
| Gypsum and anhydrite | 3,474 | 3,967 | 3,959 |
| Blast furnace slag | 49 | 27 | 97 |
| Fly ash | 870 | 841 | 796 |
| Other, n.e.c | 103 | 296 | 311 |
| Total | 113,528 | 124,798 | 121,350 |

[1] Includes Puerto Rico.

## MASONRY CEMENT

Production of masonry cement remained at 3.3 million tons. At yearend, 96 plants were manufacturing masonry cement in the United States. Two plants producing masonry cement exclusively were Cheney Lime & Cement Co., Allgood, AL, and Riverton Corp., Riverton, VA.

**Table 6.—Masonry cement production and stocks in the United States, by district**

| District | 1984 Plants active during year | 1984 Production (thousand short tons) | 1984 Stocks[1] at mills, Dec. 31 (thousand short tons) | 1985 Plants active during year | 1985 Production (thousand short tons) | 1985 Stocks[1] at mills, Dec. 31 (thousand short tons) |
|---|---|---|---|---|---|---|
| New York and Maine | 4 | 77 | 14 | 4 | 71 | 13 |
| Pennsylvania, eastern | 6 | 240 | 31 | 6 | 233 | 37 |
| Pennsylvania, western | 3 | 68 | 12 | 3 | 73 | 14 |
| Maryland, Virginia, West Virginia | 5 | 276 | 27 | 5 | 294 | 21 |
| Ohio | 4 | 103 | 23 | 4 | 113 | 26 |
| Michigan and Wisconsin | 5 | 206 | 55 | 6 | 203 | 47 |
| Indiana and Kentucky | 5 | 393 | 69 | 5 | 395 | 68 |
| Illinois | 2 | W | W | 1 | W | W |
| Georgia and Tennessee | 4 | 171 | 24 | 4 | 188 | 23 |
| South Carolina | 2 | W | W | 2 | W | W |
| Florida | 5 | 390 | 20 | 4 | 395 | 22 |
| Alabama | 7 | 236 | 29 | 7 | 256 | 37 |
| Arkansas, Louisiana, Mississippi | 3 | 97 | 8 | 3 | 79 | 10 |
| South Dakota | 1 | 6 | 2 | 1 | 4 | 2 |
| Iowa | 3 | 40 | 8 | 3 | 42 | 11 |
| Missouri | 3 | 143 | 23 | 4 | 139 | 26 |
| Kansas and Nebraska | 6 | 71 | 32 | 6 | 56 | 30 |
| Oklahoma | 3 | 52 | 9 | 3 | 46 | 11 |
| Texas, northern | 7 | 219 | 18 | 7 | 199 | 18 |
| Texas, southern | 5 | 73 | 9 | 5 | 64 | 8 |
| Idaho, Montana, Utah | 4 | 7 | 6 | 2 | 3 | 4 |
| Colorado and Wyoming | 2 | W | W | 2 | W | W |
| Alaska, Oregon, Washington | 1 | W | W | 3 | 9 | 6 |
| Arizona, Nevada, New Mexico | 3 | 95 | 7 | 3 | 98 | 5 |
| California, northern | -- | -- | -- | 1 | W | W |
| California, southern | 1 | W | W | 1 | W | W |
| Hawaii | 2 | 5 | 2 | 1 | 6 | 1 |
| Other | -- | 318 | 42 | -- | 292 | 15 |
| Total or average | 96 | 3,286 | 470 | 96 | 3,258 | [2]456 |

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Includes imported cement.
[2] Data do not add to total shown because of independent rounding.

## ALUMINOUS CEMENT

Aluminous cement, also known as calcium aluminate cement, high-alumina cement, and Cement Fondu, is a nonportland hydraulic cement. It continued to be produced at the following three plants in the United States: Lehigh Portland Cement, Buffington, IN; Lone Star Lafarge Inc., Chesapeake, VA; and Aluminum Co. of America, Bauxite, AR.

## ENERGY

Approximately 81% of the energy consumed in cement production was in the form of fuel for kiln firing to produce clinker. Average energy consumption per ton of clinker was 4.6 million British thermal units (Btu).

The average consumption of electrical energy decreased slightly to 138.2 kilowatt hours per ton. Assuming a 40% energy efficiency in conversion of fuel to electrical energy, this represents a fuel equivalent of 1.2 million Btu per ton. Thus, average fuel consumption for kiln firing plus electrical energy, primarily for finish grinding, was approximately 5.8 million Btu per ton.

Average fuel consumption for kiln firing in wet-process plants, 5.6 million Btu per ton, was 33% higher than average fuel consumption in dry-process plants, 4.2 million Btu per ton. Approximately 56% of clinker production was by the dry process.

Kilns without preheaters averaged 5.7 million Btu per ton of clinker produced; those with suspension preheaters averaged 3.9 million Btu per ton, and those with grate-type preheaters averaged 5.4 million Btu per ton.

Coal accounted for 95% of kiln fuel consumption, natural gas accounted for 4%, and oil and waste fuel accounted for the remainder.

Energy-saving additives for cement production, such as fly ash and blast furnace slags, continued to be used. The use of fly ash decreased 5% to 796,000 tons. The use of slags increased 259% to 97,000 tons, the first increase following 5 consecutive years of decline.

## Table 7.—Clinker produced in the United States,[1] by fuel

| Fuel | Clinker produced | | | Fuel consumed | | |
|---|---|---|---|---|---|---|
| | Plants active during year | Quantity (thousand short tons) | Percent of total | Coal[2] (thousand short tons) | Oil (thousand 42-gallon barrels) | Natural gas (thousand cubic feet) |
| 1984: | | | | | | |
| Coal | 26 | 12,923 | 18.5 | 2,822 | -- | -- |
| Coal and oil | 29 | 15,454 | 22.2 | 2,862 | 373 | -- |
| Coal and natural gas | 59 | 30,405 | 43.6 | 5,302 | -- | 10,461,227 |
| Oil and natural gas | 1 | 72 | .1 | -- | 56 | 95,210 |
| Coal, oil, natural gas | 17 | 10,879 | 15.6 | 2,066 | 311 | 3,570,680 |
| Total | 132 | 69,733 | 100.0 | 13,052 | 740 | 14,127,117 |
| 1985: | | | | | | |
| Coal | 25 | 13,435 | 20.0 | 2,631 | -- | -- |
| Coal and oil | 25 | 15,450 | 23.0 | 2,710 | 510 | -- |
| Coal and natural gas | 53 | 28,886 | 43.0 | 4,831 | -- | 8,020,775 |
| Oil and natural gas | -- | -- | -- | -- | 35 | -- |
| Coal, oil, natural gas | 23 | 9,405 | 14.0 | 1,434 | 210 | 2,623,539 |
| Total | 126 | 67,176 | 100.0 | 11,606 | 755 | 10,644,314 |

[1] Includes Puerto Rico.
[2] Includes 0.6% anthracite, 94.7% bituminous, and 4.7% petroleum coke in 1984; 1.3% anthracite, 94.5% bituminous, and 4.2% petroleum coke in 1985.

## Table 8.—Clinker produced and fuel consumed by the portland cement industry in the United States,[1] by process

| Process | Clinker produced | | | Fuel consumed | | |
|---|---|---|---|---|---|---|
| | Plants active during year | Quantity (thousand short tons) | Percent of total | Coal[2] (thousand short tons) | Oil (thousand 42-gallon barrels) | Natural gas (thousand cubic feet) |
| 1984: | | | | | | |
| Wet | 58 | 25,950 | 37.2 | 5,672 | 199 | 5,015,128 |
| Dry | 69 | 40,653 | 58.3 | 6,819 | 526 | 8,241,622 |
| Both | 5 | 3,130 | 4.5 | 561 | 15 | 870,367 |
| Total | 132 | 69,733 | 100.0 | 13,052 | 740 | 14,127,117 |
| 1985: | | | | | | |
| Wet | 53 | 26,066 | 38.8 | 5,227 | 210 | 4,341,724 |
| Dry | 68 | 37,797 | 56.3 | 5,800 | 525 | 5,471,841 |
| Both | 5 | 3,313 | 4.9 | 579 | 20 | 830,749 |
| Total | 126 | 67,176 | 100.0 | 11,606 | 755 | 10,644,314 |

[1] Includes Puerto Rico.
[2] Includes 0.6% anthracite, 94.7% bituminous, and 4.7% petroleum coke in 1984; 1.3% anthracite, 94.5% bituminous, and 4.2% petroleum coke in 1985.

## Table 9.—Electric energy used at portland cement plants in the United States,[1] by process

| Process | Electric energy used | | | | | | Finished cement produced (thousand short tons) | Average electric energy used per ton of cement produced (kilowatt hours) |
|---|---|---|---|---|---|---|---|---|
| | Generated at portland cement plants | | Purchased | | Total | | | |
| | Active plants | Quantity (million kilowatt hours) | Active plants | Quantity (million kilowatt hours) | Quantity (million kilowatt hours) | Percent | | |
| 1984: | | | | | | | | |
| Wet | -- | -- | 58 | 3,634 | 3,634 | 34.4 | 27,942 | 130.1 |
| Dry[2] | 5 | 432 | 80 | 6,013 | 6,445 | 60.9 | 44.026 | 146.4 |
| Both | -- | -- | 5 | 500 | 500 | 4.7 | 3,446 | 145.1 |
| Total or average | 5 | 432 | 143 | 10,147 | 10,579 | 100.0 | 75,418 | 140.3 |
| Percent of total electric energy used | -- | 4.1 | -- | 95.9 | -- | -- | -- | -- |
| 1985: | | | | | | | | |
| Wet | 2 | 108 | 49 | 3,235 | 3,338 | 35.0 | 25,846 | 129.1 |
| Dry[2] | 5 | 548 | 66 | 5,118 | 5,666 | 59.4 | 39,585 | 143.1 |
| Both | -- | -- | 5 | 533 | 533 | 5.6 | 3,601 | 148.0 |
| Total or average | 7 | 651 | 120 | 8,886 | 9,537 | 100.0 | 69,032 | 138.2 |
| Percent of total electric energy used | -- | 6.8 | -- | 93.2 | -- | -- | -- | -- |

[1] Includes Puerto Rico. Includes grinding plants and white cement facilities.

[2] Includes data for grinding plants.

## TRANSPORTATION

The pattern of cement transport did not differ significantly from that of recent years. U.S. shipments of portland cement to consumers were primarily in bulk (95%), by truck (93.4%), and were made directly from cement manufacturing plants (66%), rather than from distribution terminals.

With respect to shipments of cement from plants to terminals, the preferred modes of transportation were railroads, 42%, and waterways, 37%. Transportation by truck accounted for 19%. Cement used at producing plants accounted for the remaining 2%.

### Table 10.—Shipments of portland cement from mills in the United States,[1] in bulk and in containers, by type of carrier

(Thousand short tons)

| Type of carrier | Shipments from plant to terminal | | Shipments to ultimate consumer | | | | Total shipments |
|---|---|---|---|---|---|---|---|
| | | | From terminal to consumer | | From plant to consumer | | |
| | In bulk | In containers | In bulk | In containers | In bulk | In containers | |
| 1984: | | | | | | | |
| Railroad | 8,776 | 78 | 565 | 16 | 3,030 | 34 | 3,645 |
| Truck | 3,777 | 171 | 22,415 | 607 | 47,026 | 3,623 | 73,671 |
| Barge and boat | 7,922 | 90 | 145 | -- | 305 | -- | 450 |
| Unspecified[2] | 462 | -- | 34 | -- | 74 | 5 | 113 |
| Total | 20,937 | 339 | 23,159 | 623 | 50,435 | 3,662 | [3] [4]77,881 |
| 1985: | | | | | | | |
| Railroad | 9,089 | 89 | 1,079 | 1 | 3,464 | 75 | 4,619 |
| Truck | 4,073 | 185 | 22,885 | 554 | 48,536 | 3,474 | 75,449 |
| Barge and boat | 7,866 | 89 | 472 | -- | 158 | -- | 630 |
| Unspecified[2] | 520 | -- | 6 | -- | 36 | 4 | 46 |
| Total | 21,548 | 363 | 24,442 | 555 | 52,194 | 3,553 | [3]80,744 |

[1] Includes Puerto Rico.
[2] Includes cement used at plant.
[3] Bulk shipments were 94.5%, and container (bag) shipments were 5.5%.
[4] Data do not add to total shown because of independent rounding.

## CONSUMPTION AND USES

Cement consumption in the United States, excluding Puerto Rico, increased 4.0% to 87.5 million tons. Domestic producers' shipments increased 4% to 83.0 million tons, which included 5.5 million tons of imported cement. Additional imports of 4.0 million tons were shipped by other importers.

Domestic cement shipments to all regions of the United States increased except for the South. The Northeast region registered the largest increase, 12%, followed by the West, 7%, and the North Central, 3%.

The end-use distribution pattern for portland cement did not differ significantly from that of recent years. Ready-mixed concrete producers were the primary consumers, accounting for 70% of the total quantity shipped by domestic producers. Manufacturers of concrete products used 12% of the total to produce concrete blocks, pipes, and precast, prestressed, and other concrete products. The remainder was used by highway contractors; building contractors; cement dealers; Federal, State, and other government agencies; and other miscellaneous users.

According to the U.S. Department of Commerce, the value of U.S. construction put in place increased 10% to $343 billion.[5] Of this total value, 33% was in private housing; 26% was in private industrial and commercial buildings, including farms; 6% was in public buildings; 6% was in highways and streets; and the remainder was in other public construction and public utilities.

Total value of private construction put in place increased 9% to $281 billion. The value of residential units put in place increased slightly to $148 billion and that of industrial-commercial construction put in place increased 19% to $88 billion. Total value of public construction put in place increased 5% to $58 billion; of which, the value of public buildings increased 13% to $20 billion, highway construction increased 23% to $20 billion, and other public construction remained essentially unchanged at $14 billion, with military facilities and conservation and development areas accounting for the balance.

Housing starts were essentially unchanged at 1.74 million units, consisting of 1.07 million single units and 668,000 multiunits, according to the U.S. Department of Commerce. On a regional basis, housing starts decreased 15% in the South to 734,000 units, increased 15% in the Northeast to 194,000 units, increased slightly in the West to 401,000 units, and decreased 7% in the North Central region to 206,000 units.

**Table 11.—Portland cement shipped by producers in the United States, by district[1]**

| District | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Quantity (thousand short tons) | Value (thousands) | Average per ton | Quantity (thousand short tons) | Value (thousands) | Average per ton |
| New York and Maine | 3,263 | $163,527 | $50.12 | 3,639 | $175,255 | $48.16 |
| Pennsylvania, eastern | 4,427 | 224,707 | 50.76 | 4,272 | 236,159 | 55.28 |
| Pennsylvania, western | 1,308 | 56,882 | 43.49 | 1,263 | 51,310 | 40.62 |
| Maryland, Virginia, West Virginia | 3,412 | 167,064 | 48.96 | 3,399 | 170,949 | 50.29 |
| Ohio | 1,525 | 69,810 | 45.78 | 1,769 | 84,929 | 48.00 |
| Michigan and Wisconsin | 4,610 | 208,232 | 45.17 | 4,695 | 207,137 | 44.11 |
| Indiana and Kentucky | 2,351 | 96,039 | 40.85 | 2,389 | 102,499 | 42.90 |
| Illinois | 1,997 | 82,622 | 41.37 | 2,101 | 86,211 | 41.03 |
| Georgia and Tennessee | 2,183 | 102,569 | 46.99 | 2,162 | 101,784 | 47.07 |
| South Carolina | 2,319 | 103,891 | 44.80 | 2,207 | 104,705 | 47.44 |
| Florida | 3,564 | 172,548 | 48.41 | 3,282 | 148,908 | 45.37 |
| Alabama | 3,656 | 167,191 | 45.73 | 3,721 | 165,972 | 44.60 |
| Arkansas, Louisiana, Mississippi | 2,303 | 119,651 | 51.95 | 2,133 | 111,026 | 52.05 |
| South Dakota | 619 | 30,773 | 49.71 | 655 | 32,774 | 50.03 |
| Iowa | 1,730 | 92,699 | 53.58 | 1,618 | 77,890 | 48.13 |
| Missouri | 3,981 | 178,225 | 44.77 | 3,669 | 159,757 | 43.54 |
| Kansas and Nebraska | 2,689 | 145,717 | 54.19 | 2,550 | 138,462 | 54.29 |
| Oklahoma | 1,732 | 84,701 | 48.90 | 1,589 | 72,583 | 45.67 |
| Texas, northern | 5,029 | 300,613 | 59.78 | 5,287 | 305,355 | 57.75 |
| Texas, southern | 5,394 | 256,808 | 47.61 | 4,955 | 227,704 | 45.97 |
| Idaho, Montana, Utah | 1,724 | 94,469 | 54.80 | 1,743 | 97,943 | 56.19 |
| Colorado and Wyoming | 1,738 | 109,780 | 63.16 | 1,582 | 100,832 | 63.73 |
| Alaska, Oregon, Washington | 1,711 | 94,916 | 55.47 | 1,700 | 94,159 | 55.38 |
| Arizona, Nevada, New Mexico | 2,209 | 148,704 | 67.32 | 2,192 | 145,476 | 66.36 |
| California, northern | 2,507 | 149,566 | 59.66 | 2,595 | 158,656 | 61.13 |
| California, southern | 6,208 | 370,460 | 59.67 | 6,868 | 442,850 | 64.48 |
| Hawaii | 186 | 18,282 | 98.29 | 215 | 16,050 | 74.65 |
| Total[2] [3] or average | 74,376 | 3,810,446 | 51.23 | 74,250 | 3,817,335 | 51.41 |
| Foreign imports[4] | 2,509 | 121,935 | 48.60 | 5,532 | 252,480 | 45.64 |
| Puerto Rico | 997 | 87,568 | 87.83 | 962 | 72,602 | 75.47 |
| Grand total[3] or average | 77,881 | 4,019,948 | 51.62 | 80,744 | 4,142,417 | 51.30 |

[1] Includes Puerto Rico. Includes data for three white cement facilities as follows: California (1), Pennsylvania (1), and Texas (1). Includes data for grinding plants (13 in 1984 and 11 in 1985) as follows: Alaska (1), Florida (1 in 1984 and 2 in 1985), Michigan (2 in 1984 and 1 in 1985), New York (1), Pennsylvania (2 in 1984 and 1 in 1985), Texas (4 in 1984 and 3 in 1985) and Wisconsin (2).

[2] Includes cement produced from imported clinker.

[3] Data may not add to totals shown because of independent rounding.

[4] Cement imported and distributed by domestic producers only.

## Table 12.—Masonry cement shipped by producers in the United States,[1] by district

| District | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Quantity (thousand short tons) | Value (thousands) | Average per ton | Quantity (thousand short tons) | Value (thousands) | Average per ton |
| New York and Maine | 78 | $5,086 | $65.21 | 76 | $5,074 | $66.76 |
| Pennsylvania, eastern | 226 | 14,779 | 65.39 | 230 | 15,006 | 65.24 |
| Pennsylvania, western | 71 | 6,069 | 85.48 | 74 | 5,964 | 80.59 |
| Maryland, Virginia, West Virginia | 273 | 16,912 | 61.95 | 285 | 15,424 | 54.11 |
| Ohio | 101 | 8,092 | 80.12 | 110 | 10,412 | 94.65 |
| Michigan and Wisconsin | 216 | 14,264 | 66.04 | 211 | 13,771 | 65.26 |
| Indiana and Kentucky | 383 | 21,965 | 57.35 | 396 | 27,994 | 70.69 |
| Illinois | W | W | W | W | W | W |
| Georgia and Tennessee | 174 | 12,165 | 69.91 | 192 | 13,152 | 68.50 |
| South Carolina | W | W | W | W | W | W |
| Florida | 383 | 24,624 | 64.29 | 316 | 17,137 | 54.23 |
| Alabama | 259 | 17,247 | 66.59 | 268 | 18,113 | 67.58 |
| Arkansas, Louisiana, Mississippi | 104 | 6,738 | 64.79 | 80 | 4,803 | 60.03 |
| South Dakota | 5 | 283 | 56.60 | 4 | W | W |
| Iowa | 42 | 3,260 | 77.62 | 39 | 3,372 | 86.46 |
| Missouri | 143 | 7,033 | 49.18 | 139 | 6,630 | 47.69 |
| Kansas and Nebraska | 70 | 4,244 | 60.63 | 57 | 3,716 | 65.19 |
| Oklahoma | 49 | 3,506 | 71.55 | 43 | 2,854 | 66.37 |
| Texas, northern | 202 | 16,905 | 83.69 | 187 | 15,965 | 85.37 |
| Texas, southern | 89 | 7,503 | 84.30 | 76 | 6,149 | 80.91 |
| Idaho, Montana, Utah | 6 | 416 | 69.33 | 5 | 361 | 72.20 |
| Colorado and Wyoming | W | W | W | W | W | W |
| Alaska, Oregon, Washington | W | W | W | W | W | W |
| Arizona, Nevada, New Mexico | 94 | 7,013 | 74.61 | 99 | 7,468 | 75.43 |
| California, northern | -- | -- | -- | W | W | W |
| California, southern | W | W | W | W | W | W |
| Hawaii | 5 | 792 | 158.40 | 7 | 588 | 84.00 |
| Other | 310 | 20,980 | 67.68 | 293 | 19,143 | 65.33 |
| **Total[2] or average** | **3,281** | **219,877** | **67.02** | **3,187** | **213,096** | **66.86** |
| **Foreign imports[3]** | **([4])** | **1** | **75.62** | **62** | **3,488** | **56.25** |
| **Grand total[2] or average** | **3,281** | **219,878** | **67.02** | **3,250** | **216,584** | **66.64** |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Does not include quantities produced on the job by masons.

[2] Data may not add to totals shown because of independent rounding.

[3] Cement imported and distributed by domestic producers only. Source of imports withheld to avoid disclosing company proprietary data.

[4] Less than 1/2 unit.

## Table 13.—Cement shipments, by destination and origin[1]

(Thousand short tons)

| Destination and origin | Portland cement[2] | | | Masonry cement | | |
|---|---|---|---|---|---|---|
| | 1983 | 1984 | 1985 | 1983 | 1984 | 1985 |
| **Destination:** | | | | | | |
| **Alabama** | 1,088 | 1,204 | 1,306 | 85 | 94 | 100 |
| **Alaska[3]** | 180 | 197 | 156 | W | W | W |
| **Arizona** | 1,645 | 2,001 | 2,318 | W | W | W |
| **Arkansas** | 655 | 717 | 773 | 41 | 44 | 45 |
| **California, northern** | 2,608 | 3,166 | 3,439 | -- | W | W |
| **California, southern** | 4,427 | 6,150 | 6,691 | W | W | W |
| **Colorado** | 1,478 | 1,674 | 1,574 | 26 | 30 | 23 |
| **Connecticut[3]** | 626 | 759 | 870 | 15 | 16 | 17 |
| **Delaware[3]** | 145 | 164 | 194 | 9 | 11 | 10 |
| **District of Columbia[3]** | 116 | 105 | 116 | 1 | 1 | 1 |
| **Florida** | 4,866 | 6,253 | 6,140 | 396 | 480 | 468 |
| **Georgia** | 2,256 | 2,775 | 2,875 | 189 | 209 | 228 |
| **Hawaii** | 216 | 186 | 214 | 6 | 5 | 7 |
| **Idaho** | 268 | 276 | 236 | 1 | 1 | 1 |
| **Illinois** | 1,053 | 1,236 | 1,391 | 28 | 31 | 28 |
| **Chicago, metropolitan[3]** | 1,188 | 1,378 | 1,333 | 36 | 41 | 45 |
| **Indiana** | 1,148 | 1,248 | 1,353 | 68 | 76 | 76 |
| **Iowa** | 1,147 | 1,204 | 1,078 | 12 | 14 | 11 |
| **Kansas** | 983 | 1,243 | 1,293 | 21 | 23 | 20 |
| **Kentucky** | 813 | 978 | 1,014 | 76 | 81 | 78 |
| **Louisiana** | 2,490 | 2,650 | 2,420 | 74 | 80 | 65 |
| **Maine** | 223 | 265 | 283 | 8 | 10 | 10 |
| **Maryland** | 1,266 | 1,351 | 1,503 | 113 | 129 | 139 |
| **Massachusetts[3]** | 1,077 | 1,292 | 1,395 | 34 | 44 | 45 |
| **Michigan** | 1,457 | 1,908 | 2,108 | 70 | 90 | 104 |
| **Minnesota[3]** | 1,124 | 1,173 | 1,419 | 38 | 40 | 40 |

See footnotes at end of table.

## Table 13.—Cement shipments, by destination and origin[1] —Continued

(Thousand short tons)

| Destination and origin | Portland cement[2] | | | Masonry cement | | |
|---|---|---|---|---|---|---|
| | 1983 | 1984 | 1985 | 1983 | 1984 | 1985 |
| Destination —Continued | | | | | | |
| Mississippi | 716 | 790 | 758 | 51 | 60 | 57 |
| Missouri | 1,383 | 1,650 | 1,735 | 37 | 48 | 39 |
| Montana | 264 | 252 | 190 | 2 | 2 | 1 |
| Nebraska | 715 | 823 | 783 | 11 | 12 | 11 |
| Nevada | 459 | 503 | 637 | -- | -- | ([4]) |
| New Hampshire[3] | 260 | 314 | 374 | 8 | 15 | 15 |
| New Jersey[3] | 1,337 | 1,672 | 1,743 | 56 | 68 | 78 |
| New Mexico | 598 | 618 | 620 | 12 | 10 | 10 |
| New York, eastern | 366 | 488 | 621 | 22 | 31 | 36 |
| New York, western | 746 | 773 | 812 | 36 | 40 | 43 |
| New York, metropolitan[3] | 1,312 | 1,403 | 1,722 | 51 | 50 | 50 |
| North Carolina | 1,472 | 1,724 | 1,796 | 196 | 224 | 238 |
| North Dakota[3] | 317 | 346 | 286 | 6 | 6 | 5 |
| Ohio | 2,311 | 2,607 | 2,646 | 116 | 129 | 135 |
| Oklahoma | 1,758 | 1,751 | 1,329 | 66 | 60 | 40 |
| Oregon | 553 | 609 | 709 | 1 | ([4]) | ([4]) |
| Pennsylvania, eastern | 1,481 | 1,649 | 1,774 | 54 | 57 | 63 |
| Pennsylvania, western | 828 | 920 | 1,118 | 54 | 60 | 70 |
| Rhode Island[3] | 147 | 197 | 165 | 3 | 5 | 4 |
| South Carolina | 858 | 984 | 1,019 | 106 | 116 | 119 |
| South Dakota | 274 | 224 | 292 | 4 | 4 | 4 |
| Tennessee | 1,207 | 1,371 | 1,480 | 127 | 142 | 154 |
| Texas, northern | 4,936 | 5,466 | 5,474 | 171 | 182 | 171 |
| Texas, southern | 5,138 | 5,584 | 5,433 | 114 | 123 | 101 |
| Utah | 792 | 973 | 1,059 | 1 | 1 | 2 |
| Vermont[3] | 133 | 145 | 212 | 4 | 4 | 4 |
| Virginia | 1,646 | 1,946 | 2,116 | 147 | 166 | 177 |
| Washington | 1,077 | 1,156 | 1,208 | 6 | 7 | 6 |
| West Virginia | 444 | 445 | 387 | 29 | 29 | 29 |
| Wisconsin | 1,247 | 1,418 | 1,240 | 36 | 40 | 39 |
| Wyoming | 380 | 394 | 413 | 2 | 2 | 2 |
| U.S. total | 69,698 | 80,738 | 83,638 | 2,876 | 3,243 | 3,264 |
| Foreign countries[5] | 231 | 190 | 177 | 91 | 103 | 108 |
| Puerto Rico | 920 | 1,000 | 962 | -- | -- | -- |
| Total shipments[6] | 70,849 | 81,928 | 84,778 | 2,967 | 3,346 | 3,373 |
| Origin: | | | | | | |
| United States[7] | 67,183 | 74,376 | 74,250 | 2,921 | 3,281 | 3,187 |
| Puerto Rico | 931 | 997 | 962 | -- | -- | -- |
| Foreign:[8] | | | | | | |
| Domestic producers | 827 | 2,509 | 5,532 | 2 | ([4]) | 62 |
| Others | 1,908 | 4,046 | 4,034 | 44 | 65 | 124 |
| Total shipments[6] | 70,849 | 81,928 | 84,778 | 2,967 | 3,346 | 3,373 |

W Withheld to avoid disclosing company proprietary data; included with "Foreign countries."

[1] Includes cement produced from imported clinker and imported cement shipped by domestic producers, Canadian cement manufacturers, and other importers. Includes Puerto Rico.

[2] Excludes cement (1983—211,000 tons; 1984—225,000 tons; and 1985—253,000 tons) used in the manufacture of prepared masonry cement.

[3] Has no cement producing plants.

[4] Less than 1/2 unit.

[5] Direct shipments by producers to foreign countries and U.S. possessions and territories; includes States indicated by symbol W.

[6] Data may not add totals shown because of independent rounding.

[7] Includes cement produced from imported clinker by domestic producers.

[8] Imported cement distributed by domestic producers, Canadian cement manufacturers, and other importers. Origin of imports withheld to avoid disclosing company proprietary data.

### Table 14.—Cement shipments,[1] by region and subregion

| Region and subregion[2] | Portland cement | | | | Masonry cement | | | |
|---|---|---|---|---|---|---|---|---|
| | Thousand short tons | | Percent of grand total | | Thousand short tons | | Percent of grand total | |
| | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 |
| Northeast: | | | | | | | | |
| New England | 2,972 | 3,299 | 3.7 | 4.0 | 94 | 96 | 2.9 | 2.9 |
| Middle Atlantic | 6,905 | 7,790 | 8.5 | 9.3 | 306 | 340 | 9.4 | 10.4 |
| Total | 9,877 | 11,089 | 12.2 | 13.3 | 400 | 436 | 12.3 | 13.3 |
| South: | | | | | | | | |
| Atlantic | 15,747 | 16,148 | 19.5 | 19.3 | 1,365 | 1,409 | 42.1 | 43.2 |
| East Central | 4,338 | 4,558 | 5.4 | 5.5 | 377 | 389 | 11.6 | 11.9 |
| West Central | 16,168 | 15,429 | 20.0 | 18.4 | 489 | 423 | 15.1 | 13.0 |
| Total | 36,253 | 36,135 | 44.9 | 43.2 | 2,231 | 2,221 | 68.8 | 68.1 |
| North Central: | | | | | | | | |
| East | 9,790 | 10,067 | 12.1 | 12.0 | 407 | 427 | 12.6 | 13.1 |
| West | 6,663 | 6,886 | 8.3 | 8.2 | 147 | 129 | 4.5 | 3.9 |
| Total | 16,453 | 16,953 | 20.4 | 20.2 | 554 | 556 | 17.1 | 17.0 |
| West: | | | | | | | | |
| Mountain | 6,691 | 7,046 | 8.3 | 8.4 | 46 | 39 | 1.4 | 1.2 |
| Pacific | 11,464 | 12,417 | 14.2 | 14.9 | 12 | 13 | .4 | .4 |
| Total[3] | 18,155 | 19,463 | 22.5 | 23.3 | 58 | 52 | 1.8 | 1.6 |
| Grand total[4] | 80,738 | 83,638 | 100.0 | 100.0 | 3,243 | 3,264 | 100.0 | 100.0 |

[1] Includes imported cement shipped by domestic and Canadian cement manufacturers and other importers.
[2] Geographic regions as designated by the U.S. Department of Commerce, Bureau of the Census.
[3] Does not include proprietary data from table 13.
[4] Data may not add to totals shown because of independent rounding.

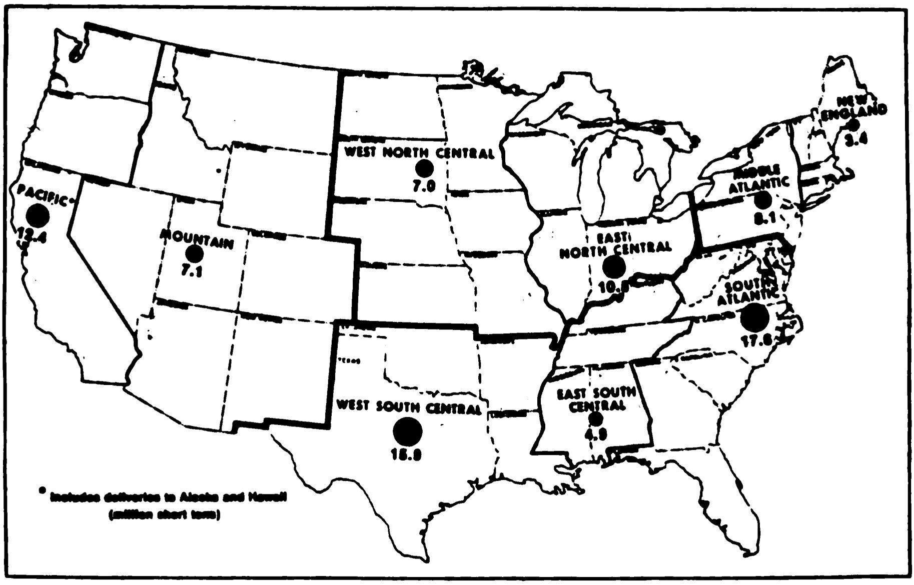

Figure 1.—Shipments of cement by geographic region of destination in 1985.

## Table 15.—Portland cement shipments in 1965, by district of origin and type of customer[1]

| District of origin | Building material dealers |  | Concrete product manufacturers |  | Ready-mixed concrete |  | Highway contractors |  | Other contractors |  | Federal, State, and other government agencies |  | Miscellaneous including own use |  | Total[2] (thousand short tons) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Quantity (thousand short tons) | Percent | Quantity (thousand short tons) | Percent | Quantity (thousand short tons) | Percent | Quantity (thousand short tons) | Percent | Quantity (thousand short tons) | Percent | Quantity (thousand short tons) | Percent | Quantity (thousand short tons) | Percent |  |
| New York and Maine | 226 | 6.2 | 559 | 15.4 | 2,517 | 69.2 | 198 | 5.4 | 120 | 3.3 | 1 | -- | 20 | .5 | 3,641 |
| Pennsylvania, eastern | 377 | 8.8 | 1,072 | 25.1 | 2,692 | 63.0 | 38 | .9 | 30 | .7 | (3) | -- | 63 | 1.5 | 4,272 |
| Pennsylvania, western | 227 | 18.0 | 214 | 16.9 | 703 | 55.6 | 72 | 5.7 | 48 | 3.8 | -- | -- | -- | -- | 1,263 |
| Maryland, Virginia, West Virginia | 177 | 5.2 | 599 | 17.6 | 2,395 | 70.5 | 72 | 2.1 | 78 | 2.3 | 40 | 1.2 | 38 | 1.1 | 3,399 |
| Ohio | 134 | 7.5 | 270 | 15.2 | 1,244 | 70.3 | 115 | 6.5 | 6 | .3 | -- | -- | 1 | .1 | 1,769 |
| Michigan and Wisconsin | 148 | 3.2 | 619 | 13.2 | 3,581 | 76.3 | 235 | 5.0 | 88 | 1.9 | 7 | .1 | 16 | .3 | 4,695 |
| Indiana and Kentucky | 129 | 5.4 | 332 | 13.9 | 1,724 | 72.2 | 123 | 5.2 | 37 | 1.5 | -- | -- | 44 | 1.8 | 2,389 |
| Illinois | 66 | 3.1 | 202 | 9.6 | 1,647 | 78.4 | 102 | 4.9 | 51 | 2.4 | -- | -- | 33 | 1.6 | 2,101 |
| Georgia and Tennessee | 166 | 7.7 | 561 | 25.9 | 1,274 | 59.0 | 31 | 1.4 | 119 | 5.5 | 2 | .1 | 8 | .4 | 2,162 |
| South Carolina | 57 | 2.6 | 386 | 17.5 | 1,662 | 75.3 | 23 | 1.0 | 52 | 2.4 | 3 | .1 | 25 | 1.1 | 2,207 |
| Florida | 425 | 13.0 | 396 | 12.0 | 2,232 | 68.0 | 81 | 2.5 | 101 | 3.1 | 14 | .4 | 32 | 1.0 | 3,282 |
| Alabama | 328 | 8.8 | 545 | 14.7 | 2,481 | 66.7 | 187 | 5.0 | 91 | 2.4 | 19 | .5 | 70 | 1.9 | 3,721 |
| Arkansas, Louisiana, Mississippi | 134 | 6.3 | 200 | 9.4 | 1,223 | 57.3 | 115 | 5.4 | 301 | 14.1 | 14 | .7 | 145 | 6.8 | 2,133 |
| South Dakota | 9 | 1.3 | 28 | 4.3 | 347 | 52.9 | 136 | 20.8 | 12 | 1.8 | -- | -- | 124 | 18.9 | 655 |
| Iowa | 53 | 3.3 | 295 | 18.2 | 963 | 59.5 | 277 | 17.1 | 8 | .5 | 6 | .4 | 16 | 1.0 | 1,618 |
| Missouri | 104 | 2.8 | 377 | 10.3 | 2,813 | 76.6 | 221 | 6.0 | 76 | 2.1 | -- | -- | 79 | 2.2 | 3,669 |
| Kansas and Nebraska | 63 | 2.5 | 136 | 5.3 | 1,756 | 68.9 | 283 | 11.1 | 271 | 10.6 | 1 | -- | 42 | 1.6 | 2,550 |
| Oklahoma | 48 | 3.0 | 70 | 4.4 | 1,103 | 69.4 | 148 | 9.3 | 192 | 12.1 | 2 | .1 | 25 | 1.6 | 1,589 |
| Texas, northern | 314 | 5.9 | 410 | 7.8 | 2,710 | 51.3 | 394 | 7.4 | 1,239 | 23.4 | 98 | 1.9 | 122 | 2.3 | 5,287 |
| Texas, southern | 277 | 5.6 | 468 | 9.4 | 3,245 | 65.5 | 266 | 5.4 | 619 | 12.5 | 22 | .4 | 58 | 1.2 | 4,955 |
| Idaho, Montana, Utah | 52 | 3.0 | 130 | 7.5 | 1,085 | 62.2 | 179 | 10.3 | 268 | 15.4 | -- | -- | 28 | 1.6 | 1,743 |
| Colorado and Wyoming | 46 | 2.9 | 173 | 10.9 | 1,156 | 73.1 | 144 | 9.1 | 58 | 3.7 | -- | -- | 5 | .3 | 1,582 |
| Alaska, Oregon, Washington | 35 | 2.1 | 113 | 6.6 | 1,320 | 77.7 | 158 | 9.3 | 32 | 1.9 | -- | -- | 41 | 2.4 | 1,700 |
| Arizona, Nevada, New Mexico | 79 | 3.6 | 354 | 16.1 | 1,456 | 66.4 | 45 | 2.1 | 239 | 10.9 | 2 | .1 | 17 | .8 | 2,192 |
| California, northern | 163 | 6.3 | 296 | 11.5 | 2,007 | 77.4 | 27 | 1.0 | 75 | 2.9 | 7 | .2 | 18 | .7 | 2,595 |
| California, southern | 439 | 6.4 | 888 | 12.9 | 5,060 | 73.6 | 12 | .2 | 387 | 5.6 | 17 | .2 | 68 | 1.0 | 6,868 |
| Hawaii | 14 | 6.5 | 30 | 14.0 | 152 | 70.7 | 2 | .9 | 11 | 5.1 | 2 | .9 | 4 | 1.9 | 215 |
| Foreign imports[4] | 73 | 2.0 | 52 | 1.5 | 5,402 | 96.8 | 3 | .1 | -- | -- | -- | -- | 3 | .1 | 5,582 |
| Total[2] or average | 4,363 | 5.5 | 9,771 | 12.2 | 55,950 | 70.1 | 3,687 | 4.6 | 4,609 | 5.8 | 257 | .3 | 1,145 | 1.5 | 79,781 |
| Puerto Rico | 467 | 48.5 | 44 | 4.6 | 430 | 44.7 | -- | -- | 18 | 1.9 | 2 | .2 | 1 | .1 | 962 |

[1] Includes Puerto Rico.

[2] Data may not add to totals shown because of independent rounding.

[3] Less than 1/2 unit.

[4] Cement imported and distributed by domestic producers only. Source of imports withheld to avoid disclosing company proprietary data.

**Table 16.—Portland cement shipped from plants in the United States,[1] by type**

| Type | 1984 Quantity (thousand short tons) | 1984 Value[2] (thousands) | 1984 Average per ton | 1985 Quantity (thousand short tons) | 1985 Value[2] (thousands) | 1985 Average per ton |
|---|---|---|---|---|---|---|
| General use and moderate heat (Types I and II) | 70,648 | $3,576,736 | $50.63 | 73,700 | $3,699,651 | $50.20 |
| High-early-strength (Type III) | 2,505 | 136,375 | 54.44 | 2,772 | 151,104 | 54.51 |
| Sulfate-resisting (Type V) | 479 | 25,633 | 53.51 | 373 | 22,645 | 60.71 |
| Oil well | 2,273 | 133,760 | 58.85 | 1,942 | 113,778 | 58.58 |
| White | 278 | 46,987 | 169.02 | 311 | 53,756 | 172.85 |
| Portland slag and portland pozzolan | 808 | 43,960 | 54.41 | 802 | 44,210 | 55.12 |
| Expansive | 50 | 3,909 | 78.18 | 35 | 3,380 | 96.57 |
| Miscellaneous[3] | 839 | 52,588 | 62.68 | 810 | 53,898 | 66.54 |
| Total[4] or average | 77,881 | 4,019,948 | 51.62 | 80,744 | 4,142,417 | 51.30 |

[1] Includes Puerto Rico.

[2] Mill value is the actual value of sales to customers, f.o.b. plant, less all discounts and allowances, less all freight charges to customer, less all freight charges from producing plant to distribution terminal if any, less total cost of operating terminal if any, less cost of paper bags and pallets.

[3] Includes waterproof, low-heat (Type IV), and regulated fast-setting cement.

[4] Data may not add to totals shown because of independent rounding.

## PRICES

The average reported unit mill value of all types of portland cement decreased slightly. The average reported unit mill value of masonry cement prepared at cement plants decreased slightly, following 4 consecutive years of increases.

According to Engineering News-Record (ENR), yearend prices of bulk portland cement for 20 U.S. cities averaged $64.98 per ton.[3] This was 25% above the average reported mill value obtained from the Bureau of Mines canvass of cement producers. The lowest ENR quotation was $55.00 per ton for New Orleans, LA, and the highest was $78.78 per ton for Boston, MA.

**Table 17.—Average mill value, in bulk, of cement in the United States[1]**

(Per short ton)

| Year | Portland cement | Prepared masonry cement[2] | All classes of cement |
|---|---|---|---|
| 1981 | $52.20 | $59.29 | $52.46 |
| 1982 | 51.04 | 61.56 | 51.48 |
| 1983 | 49.89 | 63.74 | 50.45 |
| 1984 | 51.62 | 67.02 | 52.24 |
| 1985 | 51.30 | 66.64 | 51.87 |

[1] Includes Puerto Rico. Mill value is the actual value of sales to customers, f.o.b. plant, less all discounts and allowances, less all freight charges from producing plant to distribution terminal if any, less total cost of operating terminal if any, less cost of paper bags and pallets.

[2] Masonry cement made at cement plants only.

## FOREIGN TRADE

According to trade data reported by the U.S. Department of Commerce, Bureau of the Census, the United States and its possessions and territories experienced the most dramatic increase in imports ever recorded. Imports of hydraulic cement and clinker increased 64% to a record-high level of 14.5 million tons. Canada and Spain supplied 23% each of the total, followed by Mexico, 17%; Venezuela, 11%; Japan, 8%; and 28 other countries, 18%. Cement imports accounted for about 16% of U.S. apparent consumption.

Imports of white nonstaining portland cement increased 9% to 274,000 tons. Four countries, Canada, Denmark, Mexico, and Spain, accounted for the major portion of cement imports.

Imports of clinker increased 109% to 4.6 million tons. In decreasing order, Spain, Canada, and Mexico collectively accounted for 64% of clinker imports.

Growing competition among foreign cement producers for a larger share of the U.S. market caused a flurry of domestic activity including (1) the construction of new or modification of existing import terminals, (2) the introduction of floating silo ships, (3) the idling of clinker production capacity in favor of imported clinker, and (4) the initiation of direct negotiations between foreign suppliers and domestic consumers. Among the more notable developments were (1) the formation of two lobbying organizations—the American Cement Trade Alliance (ACTA) and the Cement Free Trade Association (CFTA)—and (2) the initiation of the Cement Competitive Assessment study by the U.S. Department of Commerce.

ACTA was formed by 18 cement producers to seek Government action to deal with what it termed the adverse impact that unfairly priced or governmentally subsidized imported cement has on the U.S. cement industry. CFTA, on the other hand, was composed of five independent importers with the objective of discouraging the adoption of Federal legislation or other protectionist policies that might curtail cement imports.

The U.S. Department of Commerce Cement Competitive Assessment study focused primarily on problems and issues encountered by the U.S. cement industry during the last 15 years. The study examined cement imports or other aspects of world trade only to determine their affect on domestic supplies and prices.

Other pertinent developments with regard to foreign trade include the following:

1. Apple Valley Red-e-Mix of Minneapolis, MN, imported Spanish cement into the port of New Orleans where it was off-loaded and barged up the Mississippi River to Minneapolis.

2. Eastern Cement Corp. continued work on its 48,000-ton import terminal at Port Monatee, FL.

3. Essex Cement Co., Newark, NJ, began importing cement from Greece at its 30,000-ton import terminal. The terminal is owned jointly by a local ready-mix producer and Italian interests.

4. Falcon Pacific, a subsidiary of Saudi Research and Development Corp. of Paris, France, anchored its 75,000-ton silo ship at the Port of Los Angeles. The ship was to be continually supplied by feeder vessels.

5. Gulf Portland Cement opened a new import terminal at Port Sutton in Tampa, FL. The terminal consists of three storage silos with a capacity of 13,000 tons.

6. Lone Star Industries acquired 50% interest in the Falcon Cement Co. import terminal constructed in 1984 by the Saudi Arabian firm, Redec International, to import cement from Spain into the Houston area. The new partnership was called Lone Star-Falcon.

7. Norval Inc. of Long Island, NY, opened a new 30,000-ton import terminal at the Port of Philadelphia.

8. Tampa Cement Inc. opened an import terminal at Port Sutton in Tampa, FL. The four storage silo, 30,000-ton capacity terminal is owned by UMAR International, a Delaware corporation that is in turn owned by Spanish shareholers.

Exports of hydraulic cement and clinker increased 22% to 98,000 tons, the first increase following 3 consecutive years of decline. Canada continued to be the principal recipient of U.S. cement exports receiving 91% of the total, followed by Mexico with 4%. The remaining 5% was shipped to 41 other countries.

**Table 18.—U.S. exports of hydraulic cement and cement clinker, by country**

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Bahamas | 220 | $48 | 118 | $31 | 479 | $46 |
| Canada | 106,011 | 12,183 | 72,409 | 10,704 | 88,626 | 18,785 |
| Egypt | (1) | (1) | 1 | 1 | 1,314 | 121 |
| Korea, Republic of | 18 | 20 | 13 | 12 | 151 | 67 |
| Malagasy Republic | 18 | 16 | -- | -- | 2,010 | 281 |
| Mexico | 6,121 | 2,921 | 3,464 | 1,525 | 3,908 | 1,477 |
| Norway | 95 | 55 | 182 | 77 | 151 | 90 |
| Panama | 80 | 61 | 6 | 11 | 479 | 46 |
| Trinidad | 1,489 | 230 | 2,002 | 247 | 520 | 61 |
| Venezuela | 912 | 167 | 33 | 93 | 114 | 128 |
| Other[2] | [r]3,429 | [r]1,664 | [r]1,829 | [r]795 | 150 | 426 |
| Total | 118,398 | 17,360 | 80,007 | 13,496 | 97,897 | 21,478 |

[r] Revised.

[1] Less than 1/2 unit.

[2] Includes 40 countries in 1983, 52 in 1984, and 33 in 1985.

Source: Bureau of the Census, U.S. Department of Commerce.

## Table 19.—U.S. imports for consumption of hydraulic cement and clinker, by country

(Thousand short tons and thousand dollars)

| Country | 1983 | | | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Quantity | Value | | Quantity | Value | | Quantity | Value | |
| | | Customs | C.i.f.[1] | | Customs | C.i.f.[1] | | Customs | C.i.f.[1] |
| Canada | 2,201 | 86,198 | 92,851 | 2,945 | 116,815 | 128,920 | 3,398 | 131,117 | 145,005 |
| Colombia | 68 | 3,345 | 4,169 | 227 | 5,133 | 6,927 | 662 | 16,430 | 20,244 |
| France | 153 | 6,435 | 7,507 | 225 | 7,044 | 9,180 | 552 | 13,866 | 18,319 |
| Greece | -- | -- | -- | -- | -- | -- | 511 | 9,760 | 12,202 |
| Japan | (2) | 100 | 118 | 183 | 5,237 | 7,595 | 1,134 | 28,786 | 37,105 |
| Korea, Republic of | 69 | 3,228 | 4,144 | 332 | 10,046 | 12,129 | 484 | 26,194 | 29,738 |
| Mexico | 826 | 30,844 | 33,539 | 2,003 | 64,574 | 74,877 | 2,502 | 75,755 | 87,339 |
| Spain | 737 | 23,833 | 29,303 | 1,760 | 49,584 | 61,218 | 3,383 | 80,448 | 108,358 |
| Venezuela | 60 | 1,705 | 2,188 | 1,022 | 25,281 | 32,224 | 1,569 | 38,282 | 50,320 |
| Other | 154 | 5,751 | 7,756 | 149 | 10,493 | 10,412 | 298 | 16,791 | 20,148 |
| Total | 4,268 | 161,439 | 181,525 | 8,846 | 294,207 | 343,482 | [3]14,487 | 437,429 | 528,778 |

[1] Cost, insurance, and freight.

[2] Less than 1/2 unit.

[3] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census, U.S. Department of Commerce.

## Table 20.—U.S. imports for consumption of clinker, by country

(Thousand short tons and thousand dollars)

| Country | 1983 | | | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Quantity | Value | | Quantity | Value | | Quantity | Value | |
| | | Customs | C.i.f.[1] | | Customs | C.i.f.[1] | | Customs | C.i.f.[1] |
| Canada | 446 | 14,786 | 16,534 | 485 | 16,947 | 19,406 | 746 | 22,156 | 25,763 |
| France | 152 | 6,389 | 7,439 | 225 | 7,491 | 9,180 | 414 | 9,434 | 11,789 |
| Greece | -- | -- | -- | -- | -- | -- | 407 | 7,900 | 9,390 |
| Japan | -- | -- | -- | 69 | 2,927 | 2,693 | 291 | 6,397 | 7,840 |
| Mexico | 192 | 6,899 | 7,373 | 477 | 11,608 | 13,077 | 581 | 14,671 | 16,387 |
| Spain | 214 | 5,559 | 6,437 | 523 | 11,885 | 14,860 | 1,656 | 31,877 | 39,917 |
| Venezuela | -- | -- | -- | 294 | 5,623 | 7,484 | 290 | 5,570 | 7,022 |
| Other | -- | -- | -- | [r]141 | [r]3,319 | [r]3,935 | 248 | 5,062 | 6,305 |
| Total[2] | 1,005 | 33,633 | 37,784 | 2,215 | 59,801 | 70,635 | 4,633 | 103,067 | 124,413 |

[r] Revised.

[1] Cost, insurance, and freight.

[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census, U.S. Department of Commerce.

## Table 21.—U.S. imports for consumption of hydraulic cement and clinker, by customs district and country

(Thousand short tons and thousand dollars)

| Customs district and country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Quantity | Value | | Quantity | Value | |
| | | Customs | C.i.f.[1] | | Customs | C.i.f.[1] |
| Anchorage: | | | | | | |
| Canada | 82 | 4,839 | 5,607 | 40 | 2,441 | 3,212 |
| Japan | -- | -- | -- | 46 | 957 | 1,374 |
| Korea, Republic of | -- | -- | -- | 49 | 1,984 | 2,766 |
| Singapore | -- | -- | -- | 4 | 277 | 433 |
| Total | 82 | 4,839 | 5,607 | 139 | 5,659 | 7,785 |
| Baltimore: | | | | | | |
| Denmark | 6 | 444 | 831 | -- | -- | -- |
| Japan | (2) | 17 | 23 | (2) | 16 | 23 |
| Mexico | -- | -- | -- | 6 | 179 | 219 |
| Netherlands | (2) | 2 | 2 | (2) | 26 | 28 |

See footnotes at end of table.

## Table 21.—U.S. imports for consumption of hydraulic cement and clinker, by customs district and country —Continued

(Thousand short tons and thousand dollars)

| Customs district and country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Quantity | Value | | Quantity | Value | |
| | | Customs | C.i.f.[1] | | Customs | C.i.f.[1] |
| **Baltimore —Continued** | | | | | | |
| Spain | -- | -- | -- | 105 | 2,836 | 3,824 |
| Venezuela | -- | -- | -- | 84 | 1,055 | 1,377 |
| Total[3] | 6 | 463 | 856 | 196 | 4,112 | 5,471 |
| **Boston:** | | | | | | |
| Belgium-Luxembourg | -- | -- | -- | (2) | 12 | 15 |
| Canada | 10 | 320 | 335 | 60 | 1,819 | 1,855 |
| Spain | -- | -- | -- | 89 | 2,152 | 2,236 |
| Venezuela | -- | -- | -- | 6 | 170 | 225 |
| Total | 10 | 320 | 335 | 155 | 4,153 | 4,331 |
| **Bridgeport: Canada** | 1 | 22 | 22 | -- | -- | -- |
| **Buffalo: Canada** | 713 | 27,643 | 30,438 | 911 | 31,909 | 34,299 |
| **Charleston:** | | | | | | |
| France | -- | -- | -- | (2) | 17 | 20 |
| Germany, Federal Republic of | -- | -- | -- | (2) | 6 | 7 |
| Spain | -- | -- | -- | 130 | 2,449 | 3,240 |
| Venezuela | -- | -- | -- | 29 | 499 | 532 |
| Total[3] | -- | -- | -- | 160 | 2,971 | 3,799 |
| **Chicago:** | | | | | | |
| Belgium-Luxembourg | (2) | 10 | 11 | -- | -- | -- |
| Canada | -- | -- | -- | (2) | 1 | 1 |
| German Democratic Republic | -- | -- | -- | (2) | 2 | 3 |
| Germany, Federal Republic of | (2) | 15 | 20 | (2) | 43 | 57 |
| Japan | (2) | 1 | 1 | (2) | 6 | 9 |
| Yugoslavia | (2) | 5 | 7 | (2) | 9 | 16 |
| Total | (2) | 31 | 39 | (2) | 61 | 86 |
| **Cleveland: Yugoslavia** | (2) | 4 | 8 | -- | -- | -- |
| **Detroit:** | | | | | | |
| Belgium-Luxembourg | (2) | 6 | 7 | -- | -- | -- |
| Canada | 293 | 18,588 | 19,243 | 477 | 20,901 | 22,268 |
| Netherlands | (2) | 7 | 9 | -- | -- | -- |
| Total | 293 | 18,601 | 19,259 | 477 | 20,901 | 22,268 |
| **Duluth: Canada** | 156 | 5,077 | 6,312 | 184 | 5,936 | 7,429 |
| **El Paso:** | | | | | | |
| Canada | -- | -- | -- | (2) | 16 | 16 |
| Mexico | 318 | 11,683 | 11,683 | 541 | 18,653 | 18,653 |
| Total | 318 | 11,683 | 11,683 | 541 | 18,669 | 18,669 |
| **Great Falls:** | | | | | | |
| Canada | 2 | 130 | 130 | (2) | 61 | 61 |
| Germany, Federal Republic of | -- | -- | -- | (2) | 35 | 49 |
| Total | 2 | 130 | 130 | (2) | 96 | 110 |
| **Honolulu:** | | | | | | |
| Japan | 6 | 341 | 511 | -- | -- | -- |
| Korea, Republic of | 18 | 1,604 | 1,714 | 52 | 4,600 | 5,035 |
| Total | 24 | 1,945 | 2,225 | 52 | 4,600 | 5,035 |
| **Houston:** | | | | | | |
| Canada | -- | -- | -- | 9 | 320 | 459 |
| Colombia | 42 | 830 | 1,316 | 112 | 1,961 | 2,493 |
| Germany, Federal Republic of | (2) | 62 | 76 | (2) | 135 | 169 |
| Greece | -- | -- | -- | 29 | 711 | 1,108 |
| Italy | 29 | 964 | 985 | -- | -- | -- |
| Mexico | 124 | 2,654 | 3,250 | -- | -- | -- |
| Netherlands | -- | -- | -- | (2) | 10 | 13 |
| Spain | 230 | 5,987 | 6,767 | 518 | 11,887 | 13,937 |
| Venezuela | -- | -- | -- | 22 | 668 | 775 |
| Yugoslavia | (2) | 80 | 126 | 1 | 43 | 59 |
| Total[3] | 425 | 10,577 | 12,520 | 692 | 15,735 | 19,013 |

See footnotes at end of table.

### Table 21.—U.S. imports for consumption of hydraulic cement and clinker, by customs district and country —Continued

(Thousand short tons and thousand dollars)

| Customs district and country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Quantity | Value | | Quantity | Value | |
| | | Customs | C.i.f.[1] | | Customs | C.i.f.[1] |
| **Laredo:** | | | | | | |
| Canada | (2) | 1 | 1 | -- | -- | -- |
| Mexico | 88 | 3,210 | 3,210 | 68 | 2,368 | 2,328 |
| Venezuela | 1 | 5 | 5 | -- | -- | -- |
| Yugoslavia | (2) | 51 | 90 | -- | -- | -- |
| Total | 89 | 3,267 | 3,306 | 68 | 2,368 | 2,328 |
| **Los Angeles:** | | | | | | |
| Denmark | -- | -- | -- | 9 | 662 | 1,032 |
| France | -- | -- | -- | 3 | 16 | 19 |
| Germany, Federal Republic of | (2) | 10 | 15 | -- | -- | -- |
| Japan | 24 | 631 | 775 | 344 | 9,002 | 10,543 |
| Korea, Republic of | 243 | 6,550 | 8,027 | 294 | 17,346 | 19,216 |
| Mexico | -- | -- | -- | (2) | 3 | 3 |
| Spain | 107 | 2,823 | 3,764 | 256 | 6,288 | 8,973 |
| Taiwan | -- | -- | -- | (2) | 17 | 31 |
| Yugoslavia | 1 | 81 | 198 | 2 | 199 | 384 |
| Total[3] | 375 | 10,095 | 12,779 | 909 | 33,533 | 40,201 |
| **Miami:** | | | | | | |
| Bahamas | 2 | 68 | 90 | 8 | 219 | 246 |
| Bahrain | -- | -- | -- | 4 | 115 | 129 |
| Barbados | -- | -- | -- | 4 | 129 | 143 |
| Belgium-Luxembourg | 3 | 220 | 1,671 | 2 | 101 | 186 |
| Colombia | -- | -- | -- | 23 | 616 | 778 |
| Costa Rica | -- | -- | -- | (2) | 10 | 11 |
| Mexico | 279 | 8,460 | 10,876 | 333 | 9,841 | 12,513 |
| Spain | 284 | 7,257 | 9,583 | 272 | 7,295 | 9,455 |
| Venezuela | 230 | 5,984 | 7,362 | 579 | 14,338 | 18,814 |
| Total | 798 | 21,989 | 29,582 | 1,225 | 32,664 | 42,275 |
| **Milwaukee:** Canada | 93 | 2,844 | 3,159 | -- | -- | -- |
| **Mobile:** | | | | | | |
| Canada | (2) | 3 | 3 | -- | -- | -- |
| Greece | -- | -- | -- | 228 | 3,956 | 5,329 |
| Spain | 78 | 1,725 | 2,464 | 681 | 11,811 | 16,141 |
| Venezuela | 104 | 1,778 | 2,672 | 59 | 1,011 | 1,359 |
| Total | 182 | 3,506 | 5,139 | 968 | 16,778 | 22,829 |
| **New Orleans:** | | | | | | |
| Belgium-Luxembourg | -- | -- | -- | (2) | 16 | 19 |
| Canada | 182 | 8,151 | 11,084 | 214 | 9,682 | 13,251 |
| Colombia | 16 | 301 | 506 | -- | -- | -- |
| France | 76 | 1,727 | 2,383 | 394 | 9,572 | 13,172 |
| Guatemala | -- | -- | -- | (2) | 3 | 6 |
| Mexico | 216 | 4,780 | 6,033 | 9 | 228 | 342 |
| Spain | 65 | 2,029 | 2,620 | 151 | 3,636 | 5,767 |
| Venezuela | 81 | 2,001 | 2,780 | 197 | 4,243 | 6,079 |
| Total | 636 | 18,989 | 25,406 | 965 | 27,380 | 38,636 |
| **New York City:** | | | | | | |
| Canada | 44 | 1,406 | 1,587 | 139 | 2,366 | 3,371 |
| Colombia | -- | -- | -- | 6 | 126 | 243 |
| France | 27 | 447 | 572 | -- | -- | -- |
| Greece | -- | -- | -- | 64 | 962 | 1,499 |
| Guatemala | -- | -- | -- | 35 | 750 | 900 |
| Italy | (2) | 4 | 6 | 26 | 530 | 541 |
| Norway | -- | -- | -- | 46 | 1,753 | 3,981 |
| Spain | 413 | 12,010 | 14,994 | 576 | 16,625 | 20,877 |
| Venezuela | 131 | 2,449 | 2,914 | 66 | 1,120 | 1,549 |
| Total | 615 | 16,316 | 20,073 | 958 | 24,232 | 32,961 |
| **Nogales:** Mexico | 157 | 7,097 | 7,361 | 314 | 12,149 | 12,149 |
| **Norfolk:** | | | | | | |
| Canada | (2) | 3 | 3 | -- | -- | -- |
| France | 28 | 3,001 | 3,475 | 20 | 1,723 | 1,781 |
| Germany, Federal Republic of | -- | -- | -- | (2) | 9 | 12 |

See footnotes at end of table.

## Table 21.—U.S. imports for consumption of hydraulic cement and clinker, by customs district and country —Continued

(Thousand short tons and thousand dollars)

| Customs district and country | 1984 Quantity | 1984 Value Customs | 1984 Value C.i.f.[1] | 1985 Quantity | 1985 Value Customs | 1985 Value C.i.f.[1] |
|---|---|---|---|---|---|---|
| Norfolk —Continued | | | | | | |
| Namibia | -- | -- | -- | 8 | 218 | 281 |
| Spain | -- | -- | -- | 55 | 1,578 | 1,838 |
| Venezuela | 28 | 732 | 979 | 78 | 1,879 | 2,419 |
| Total | 56 | 3,736 | 4,457 | 161 | 5,402 | 6,326 |
| Ogdensburg: Canada | 415 | 13,168 | 13,178 | 343 | 12,456 | 12,492 |
| Pembina: Canada | 65 | 3,390 | 3,390 | 48 | 2,242 | 2,246 |
| Philadelphia: | | | | | | |
| Germany, Federal Republic of | (2) | 3 | 7 | -- | -- | -- |
| Korea, Republic of | -- | -- | -- | 22 | 880 | 930 |
| Total[3] | (2) | 3 | 7 | 22 | 880 | 930 |
| Port Arthur: | | | | | | |
| Colombia | 20 | 345 | 462 | -- | -- | -- |
| Greece | -- | -- | -- | 179 | 3,945 | 4,061 |
| Spain | -- | -- | -- | 6 | 409 | 586 |
| Venezuela | -- | -- | -- | 20 | 476 | 590 |
| Total[3] | 20 | 345 | 462 | 205 | 4,830 | 5,238 |
| Portland, ME: Canada | 21 | 763 | 763 | 6 | 278 | 278 |
| Portland, OR: | | | | | | |
| Canada | 42 | 1,695 | 1,857 | 11 | 607 | 659 |
| Japan | (2) | 40 | 42 | 51 | 1,178 | 2,011 |
| Korea, Republic of | -- | -- | -- | 19 | 489 | 625 |
| Total[3] | 42 | 1,735 | 1,899 | 81 | 2,274 | 3,296 |
| Providence: | | | | | | |
| Bahamas | -- | -- | -- | 4 | 109 | 165 |
| Canada | 4 | 107 | 358 | -- | -- | -- |
| Venezuela | 10 | 413 | 687 | 55 | 1,383 | 2,115 |
| Total[3] | 14 | 520 | 1,045 | 59 | 1,492 | 2,281 |
| St. Albans: Canada | 571 | 18,101 | 18,139 | 548 | 18,007 | 18,007 |
| San Diego: | | | | | | |
| Colombia | 40 | 652 | 462 | -- | -- | -- |
| Japan | 94 | 2,241 | 3,648 | 308 | 8,333 | 11,254 |
| Mexico | 451 | 15,581 | 19,121 | 368 | 14,008 | 15,720 |
| Venezuela | 7 | 139 | 259 | 10 | 413 | 467 |
| Total | 592 | 18,618 | 23,490 | 686 | 22,754 | 27,441 |
| San Francisco: | | | | | | |
| Belgium-Luxembourg | -- | -- | -- | (2) | 51 | 86 |
| Canada | -- | -- | -- | 34 | 1,295 | 1,447 |
| Germany, Federal Republic of | (2) | 7 | 9 | -- | -- | -- |
| Italy | -- | -- | -- | (2) | 18 | 23 |
| Japan | 60 | 2,298 | 2,559 | 157 | 3,597 | 4,446 |
| Korea, Republic of | 71 | 1,892 | 2,389 | 41 | 895 | 1,164 |
| Sweden | (2) | 8 | 10 | -- | -- | -- |
| Yugoslavia | -- | -- | -- | (2) | 3 | 6 |
| Total[3] | 131 | 4,205 | 4,967 | 238 | 5,859 | 7,173 |
| San Juan, PR: | | | | | | |
| Barbados | 5 | 240 | 294 | 30 | 1,094 | 1,430 |
| Belgium-Luxembourg | 9 | 884 | 1,297 | 10 | 841 | 1,292 |
| Brazil | 1 | 39 | 45 | 1 | 70 | 89 |
| Canada | 1 | 1 | 1 | -- | -- | -- |
| Colombia | 48 | 1,170 | 1,331 | 74 | 1,747 | 2,126 |
| Costa Rica | 19 | 1,039 | 1,261 | 1 | 15 | 35 |
| Denmark | 1 | 146 | 175 | 2 | 125 | 228 |
| Dominican Republic | 6 | 206 | 262 | 19 | 350 | 485 |
| Germany, Federal Republic of | -- | -- | -- | 2 | 126 | 191 |
| Honduras | -- | -- | -- | 3 | 102 | 157 |
| Panama | 24 | 231 | 272 | 6 | 280 | 305 |
| Spain | 12 | 598 | 833 | 98 | 2,780 | 3,184 |
| Venezuela | 8 | 293 | 447 | 84 | 2,812 | 3,541 |
| Total[3] | 135 | 4,847 | 6,218 | 329 | 10,342 | 13,063 |

See footnotes at end of table.

## Table 21.—U.S. imports for consumption of hydraulic cement and clinker, by customs district and country —Continued

(Thousand short tons and thousand dollars)

| Customs district and country | 1984 |  |  | 1985 |  |  |
|---|---|---|---|---|---|---|
|  | Quantity | Value |  | Quantity | Value |  |
|  |  | Customs | C.i.f.[1] |  | Customs | C.i.f.[1] |
| **Savannah:** |  |  |  |  |  |  |
| Germany, Federal Republic of | (²) | 5 | 6 | -- | -- | -- |
| Spain | -- | -- | -- | 37 | 339 | 390 |
| Venezuela | 10 | 279 | 347 | 37 | 1,242 | 1,508 |
| Total | 10 | 284 | 353 | 74 | 1,581 | 1,898 |
| **Seattle:** |  |  |  |  |  |  |
| Canada | 251 | 10,563 | 11,761 | 368 | 14,839 | 16,239 |
| Italy | -- | -- | -- | (²) | 1 | 2 |
| Japan | (²) | 22 | 37 | 227 | 5,696 | 7,446 |
| Yugoslavia | -- | -- | -- | (²) | 8 | 19 |
| Total | 251 | 10,585 | 11,798 | 596 | 20,544 | 23,706 |
| **Tampa:** |  |  |  |  |  |  |
| Colombia | 10 | 233 | 338 | 286 | 7,078 | 8,840 |
| Costa Rica | (²) | 3 | 3 | -- | -- | -- |
| Denmark | 26 | W | W | 61 | W | W |
| France | 94 | W | W | 186 | W | W |
| Germany, Federal Republic of | (²) | 16 | 20 | -- | -- | -- |
| Greece | -- | -- | -- | 11 | 186 | 206 |
| Mexico | 362 | 10,645 | 12,803 | 862 | 20,328 | 25,340 |
| Spain | 565 | 17,143 | 19,990 | 401 | 10,176 | 12,701 |
| Venezuela | 414 | 11,884 | 13,620 | 230 | 6,536 | 8,448 |
| Total[3] | 1,469 | 45,691 | 53,345 | 1,987 | 58,631 | 72,760 |
| **Virgin Islands of the United States:** |  |  |  |  |  |  |
| Barbados | -- | -- | -- | (²) | 17 | 22 |
| Colombia | 2 | 128 | 129 | 18 | 814 | 865 |
| Dominican Republic | 4 | 120 | 142 | 6 | 229 | 263 |
| Leeward and Windward Islands | 7 | 285 | 441 | (²) | 6 | 9 |
| Mexico | 8 | 464 | 513 | -- | -- | -- |
| Panama | 2 | 73 | 91 | 4 | 177 | 179 |
| United Kingdom | -- | -- | -- | (²) | 7 | 10 |
| Venezuela | -- | -- | -- | 10 | 276 | 320 |
| Total | 23 | 1,070 | 1,316 | 38 | 1,526 | 1,668 |
| **Wilmington:** |  |  |  |  |  |  |
| Brazil | 2 | 72 | 84 | -- | -- | -- |
| Colombia | 49 | 1,474 | 2,130 | 142 | 4,094 | 4,889 |
| Spain | 6 | 167 | 202 | 6 | 169 | 205 |
| Venezuela | -- | -- | -- | 4 | 162 | 202 |
| Total | 57 | 1,718 | 2,416 | 152 | 4,425 | 5,296 |
| Grand total[3] | 8,846 | 294,207 | 343,482 | 14,487 | 437,429 | 523,773 |

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Cost, insurance, and freight.

[2] Less than 1/2 unit.

[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census, U.S. Department of Commerce.

### Table 22.—U.S. imports for consumption of cement and clinker

(Thousand short tons and thousand dollars)

| Year | Roman, portland, other hydraulic cement | | Hydraulic cement clinker | | White nonstaining portland cement | | Total[1] | |
|---|---|---|---|---|---|---|---|---|
| | Quantity | Value (customs) | Quantity | Value (customs) | Quantity | Value (customs) | Quantity | Value (customs) |
| 1981 | 2,654 | 94,653 | 1,226 | 46,447 | 117 | 10,140 | 3,997 | 151,240 |
| 1982 | 2,369 | 81,710 | 470 | 18,385 | 90 | 10,791 | 2,929 | 110,886 |
| 1983 | 3,104 | 109,791 | 1,005 | 33,633 | 160 | 18,014 | 4,268 | 161,439 |
| 1984 | 6,379 | 204,899 | 2,215 | 59,801 | 252 | 29,507 | 8,846 | 294,207 |
| 1985 | 9,581 | 306,472 | 4,633 | 103,067 | 274 | 27,890 | 14,487 | 437,429 |

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census, U.S. Department of Commerce.

## WORLD REVIEW

World cement production increased slightly to 1.07 billion tons. The United States accounted for 7% of world production. In order of production, China, the U.S.S.R., and Japan were the three principal producing countries and accounted for 36% of world production. The 10 largest cement producing countries accounted for 60% of the world's total. Exporting countries continued to view the United States as a primary market for their excess cement. Thirty-three countries exported cement to the United States in 1985 compared with 23 in 1984.

Rock Products' magazine report on the world cement industry described the following significant activities in cement plant construction, modernization, and expansion:[4]

**Australia.**—Adelaide Brighton Cement commissioned its 550,000-ton-per-year grinding plant. The new plant will serve markets in Brisbane, southern Queensland, and northern New South Wales.

**Belgium.**—S.A. des Cimenteries CBR completed work on its 2,870-ton-per-day clinker production line at its Antoing plant. The line included a five-stage preheater kiln with precalciner and is designed to burn low-volatile fuels.

**Egypt.**—Egypt continued to vigorously expand its cement production capacity by putting into operation five new kilns: a 3,600-ton-per-day kiln at Tourah Portland Cement Co., Tourah plant; one 4,900-ton-per-day and one 5,500-ton-per-day kiln at Helwan Portland Cement Co.'s Helwan and Assiut plants, respectively; a 4,900-ton-per-day kiln at National Cement Co.'s, Helwan plant; and a 4,900-ton-per-day kiln at Suez Cement Co.'s Quattamia plant.

**France.**—Ciments Français finished modernizing its facilities at Beaucaire by adding a five-stage preheater kiln with a precalcining system, which increased production by 3,000 tons per day. The company also added a precalciner and traveling grate cooler to the Dopol kiln system at its Bussac plant, which increased production by nearly 900 tons per day.

**India.**—The Indian cement industry continued its program of plant construction, modernization, and expansion. Kesoram Industry and Cotton Mills, Hyderabad, put its new 1,980-ton-per-day preheater-precalciner kiln and 150-ton-per-day raw material roller mill into operation; Cement Corp. of India added a new 3,300-ton-per-day dry-process kiln and coal grinding system to its Neemuch plant; Mysore Cements Ltd. put a new 1,650-ton-per-day dry-process plant with a five-stage preheater kiln into operation at Damoh; the Indian Rayon Corp. commissioned its 1,650-ton-per-day dry-process plant with preheater kiln at Rayon; Raymond Cement Works put into operation its expanded 4,200-ton-per-day dry-process five-stage preheater-precalciner plant; Shree Cement Ltd. commissioned its 2,000-ton-per-day Beawar plant and started up its Sikka plant, a 2,800-ton-per-day operation.

**Korea, Republic of.**—Halla Cement Manufacturing Co. completed work on its 1.3-million-ton-per-year dry-process preheater-precalciner plant; Hyundai Cement Co. Ltd. expanded capacity of its Danyang plant from 1.5 to 3.3 million tons per year; and Sung Shin Cement Industrial Co. Ltd. expanded the capacity of its Danyang plant from 2.8 million to 3.5 million tons per year.

**South Africa, Republic of.**—Pretoria Portland Cement Ltd. began operating its 660,000-ton-per-year plant at Dwaalboom, Northern Transvaal, and Blue Circle Industries upgraded its No. 6 kiln at its Lichtenburg plant in Western Transvaal, increasing its clinker capacity by 550,000 tons per year.

**United Kingdom.**—Blue Circle Industries 5-year program to modernize its cement manufacturing and distribution facilities was virtually complete with the conversion of its Cauldon plant at Staffordshire and the Dunbar operation in Lothian to single precalciner kiln operations.

## Table 23.—Hydraulic cement: World production, by country[1]

(Thousand short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Afghanistan[2] | 85 | 96 | [r][e]100 | [r][e]90 | [3]85 |
| Albania[e] | [r]870 | [r]915 | [r]925 | [r]925 | 935 |
| Algeria[e] | [3]4,916 | [r]4,850 | [r]5,300 | [r]6,100 | 6,100 |
| Angola[e] | 276 | 276 | 248 | 386 | 386 |
| Argentina | 7,331 | 6,199 | 6,198 | [r][e]5,644 | 5,500 |
| Australia | [r]6,620 | 6,332 | 5,331 | 6,022 | 6,600 |
| Austria | 5,829 | 5,525 | 5,409 | 5,400 | 5,500 |
| Bahamas | 32 | 71 | 29 | (4) | -- |
| Bangladesh[5] | 380 | 360 | 338 | 301 | [3]265 |
| Barbados | -- | -- | -- | [e]165 | 220 |
| Belgium | 7,376 | 6,967 | 6,304 | 6,300 | 5,800 |
| Benin | 327 | 347 | [e]331 | [e]331 | 331 |
| Bolivia | 413 | 358 | 361 | 360 | 330 |
| Brazil | 28,716 | 28,268 | 23,005 | [e]27,558 | 29,800 |
| Bulgaria | 6,000 | 6,188 | 6,221 | 6,302 | [3]5,749 |
| Burma | 350 | 379 | 369 | 343 | [3]526 |
| Cameroon | [e]569 | 584 | 672 | (6) | NA |
| Canada | 11,183 | 9,288 | 8,676 | 9,489 | [3]10,537 |
| Chile | 2,054 | 1,248 | 1,383 | 1,532 | 1,430 |
| China | 92,594 | 103,697 | 119,325 | 133,468 | 157,100 |
| Colombia | 4,915 | 5,546 | 5,204 | 5,816 | [3]5,859 |
| Congo | 54 | 43 | 17 | (6) | NA |
| Costa Rica | 507 | 467 | 425 | [e]386 | 386 |
| Cuba | 3,629 | 3,487 | 3,562 | 3,689 | [3]3,483 |
| Cyprus | 1,141 | 1,177 | 1,039 | 940 | [3]727 |
| Czechoslovakia | 11,735 | 11,381 | 11,572 | 11,607 | 11,300 |
| Denmark | 1,766 | 1,951 | 1,827 | 1,839 | [3]1,917 |
| Dominican Republic | 1,049 | 1,046 | 1,217 | 1,260 | 1,270 |
| Ecuador | 1,365 | 1,747 | 1,593 | 1,636 | 1,540 |
| Egypt | 3,857 | 4,696 | 6,063 | [r][e]7,200 | 8,600 |
| El Salvador | 505 | 461 | 476 | 449 | 440 |
| Ethiopia[e] | 143 | 154 | 165 | 176 | 176 |
| Fiji | [r]102 | 97 | 121 | 108 | [3]103 |
| Finland | [r]2,001 | [r]2,053 | 2,102 | 1,814 | 1,760 |
| France | 31,117 | 28,825 | 27,011 | 25,049 | 25,400 |
| Gabon | 165 | 193 | 132 | 229 | 230 |
| German Democratic Republic | 13,453 | 12,920 | 12,987 | 12,737 | 13,000 |
| Germany, Federal Republic of | 34,721 | 33,155 | 33,583 | 31,867 | 32,000 |
| Ghana | 437 | 322 | [e]320 | [e]320 | 380 |
| Greece | [r]14,264 | [r]14,176 | 15,648 | 14,904 | 14,900 |
| Guadeloupe[e] | [3]176 | 176 | 176 | 176 | 176 |
| Guatemala | 567 | 558 | 498 | 866 | 870 |
| Haiti | 260 | 234 | [e]238 | [e]243 | 243 |
| Honduras | 343 | 306 | 535 | [e]551 | 550 |
| Hong Kong | 1,673 | 1,582 | 1,892 | 2,037 | [3]2,023 |
| Hungary | 5,109 | 4,816 | 4,677 | 4,569 | [3]4,054 |
| Iceland | 134 | 137 | 127 | 130 | [3]126 |
| India | 22,884 | 24,800 | 27,950 | 32,000 | [3]36,431 |
| Indonesia | 7,596 | 8,268 | 9,025 | 9,765 | 11,000 |
| Iran[e] | 8,818 | 10,472 | 11,023 | 11,574 | 12,100 |
| Iraq[e] | [3]6,173 | 6,173 | 6,173 | 8,818 | 8,818 |
| Ireland | 2,136 | 1,742 | 1,638 | 1,518 | 1,540 |
| Israel | 2,271 | 2,418 | 2,269 | 3,377 | 2,400 |
| Italy | 45,804 | 43,793 | 43,229 | 41,648 | 44,000 |
| Ivory Coast | 1,323 | 1,213 | 702 | 591 | 590 |
| Jamaica | 182 | 288 | 305 | 288 | 265 |
| Japan | 93,506 | 88,943 | 89,167 | 86,928 | [3]80,311 |
| Jordan | 1,068 | 876 | 1,401 | 2,192 | 2,340 |
| Kenya | [e]1,433 | [e]1,433 | 1,411 | 1,283 | 1,200 |
| Korea, North[e] | 8,818 | 8,818 | 8,818 | 8,818 | 8,818 |
| Korea, Republic of | 17,215 | 19,717 | 23,459 | 22,501 | [3]22,514 |
| Kuwait | 1,707 | 1,712 | 1,239 | 1,305 | 1,200 |
| Lebanon | 2,636 | 1,874 | 1,653 | 1,378 | 1,100 |
| Liberia | 95 | 88 | 94 | 93 | 105 |
| Libya[e] | 3,527 | 4,409 | 5,512 | 6,614 | 7,200 |
| Luxembourg | 377 | 379 | 389 | 375 | 350 |
| Madagascar | 39 | 40 | [e]39 | [e]39 | 39 |
| Malawi | 86 | [r]59 | 78 | 77 | 70 |

See footnotes at end of table.

### Table 23.—Hydraulic cement: World production, by country[1] —Continued

(Thousand short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Malaysia | 3,123 | 3,443 | 3,573 | 3,824 | 3,600 |
| Mali | [e]22 | 30 | [e]22 | 28 | 28 |
| Martinique[e] | [3]198 | 220 | 220 | 220 | 220 |
| Mauritania | 66 | 66 | [e]66 | (4) | -- |
| Mexico | 19,817 | 21,272 | 18,814 | 20,322 | [3]22,686 |
| Mongolia | 231 | 386 | 370 | 386 | 440 |
| Morocco | 3,975 | [r]4,122 | 4,242 | 3,955 | [3]4,075 |
| Mozambique | 256 | 386 | 463 | [e]496 | 496 |
| Nepal | 34 | [e]28 | 50 | 43 | [3]35 |
| Netherlands | 3,655 | 3,420 | 3,425 | 3,501 | 3,450 |
| New Caledonia | 55 | 59 | [e]66 | [e]66 | 66 |
| New Zealand | [r]979 | [r]1,175 | 1,054 | 1,113 | 1,200 |
| Nicaragua[e] | [3]184 | 110 | 110 | 110 | 110 |
| Niger[e] | [3]41 | 42 | 42 | 42 | 42 |
| Nigeria[e] | [3]2,756 | 3,968 | 3,968 | 3,968 | 3,968 |
| Norway | 2,025 | 1,969 | 1,783 | 1,607 | [3]1,764 |
| Pakistan | [r]3,954 | [r]4,076 | 5,443 | 5,178 | [3]5,212 |
| Panama | 573 | 386 | 360 | 335 | 330 |
| Paraguay | 172 | 122 | 169 | 120 | 165 |
| Peru | 3,395 | 2,855 | 2,535 | [e]2,425 | 2,425 |
| Philippines[7] | 4,508 | 4,795 | 4,831 | 4,040 | 3,500 |
| Poland | 15,681 | 17,747 | 17,857 | 18,409 | [3]16,535 |
| Portugal | 6,280 | 6,393 | 6,683 | 6,106 | 6,600 |
| Qatar | 284 | [r]252 | 413 | 527 | 527 |
| Romania | 16,255 | 16,529 | 15,397 | 15,653 | [3]13,448 |
| Saudi Arabia | 5,219 | 7,885 | 8,957 | 9,921 | 9,900 |
| Senegal | 410 | 401 | 435 | 424 | 425 |
| Singapore | 2,484 | 2,971 | 3,476 | 3,110 | [3]2,195 |
| South Africa, Republic of | 8,923 | 8,830 | 8,705 | 9,025 | [3]7,754 |
| Spain (including Canary Islands)[8] | 31,693 | 32,594 | 33,771 | 28,038 | 28,100 |
| Sri Lanka | 708 | [e]717 | 558 | [e]551 | 660 |
| Sudan | 165 | 202 | [e]220 | 194 | [3]213 |
| Suriname | 78 | 79 | 82 | [e]55 | 55 |
| Sweden | 2,555 | [r]2,540 | 2,469 | 2,604 | 2,900 |
| Switzerland | 4,793 | 4,513 | 4,564 | 4,609 | 4,630 |
| Syria | [r]2,553 | [r]2,864 | 3,996 | 4,720 | 3,900 |
| Taiwan | 15,809 | 14,806 | 16,325 | 15,690 | [3]15,893 |
| Tanzania | [5]433 | [e]441 | [e]463 | 408 | 440 |
| Thailand | 6,904 | 7,285 | 8,006 | 9,083 | 9,040 |
| Togo | 314 | 308 | 256 | 268 | 310 |
| Trinidad and Tobago | 154 | 209 | 430 | 447 | 450 |
| Tunisia | 2,227 | 1,965 | 3,142 | 3,649 | 3,900 |
| Turkey | 16,582 | 17,392 | 14,986 | 17,348 | 17,600 |
| Uganda | 7 | 19 | [r] [e]22 | [r] [e]22 | 22 |
| U.S.S.R | 140,180 | 136,335 | 141,268 | 143,453 | 144,000 |
| United Arab Emirates | [r]1,896 | [r]2,447 | 2,280 | 4,415 | 4,400 |
| United Kingdom | 14,031 | 14,288 | 14,767 | 14,860 | [3]14,709 |
| United States (including Puerto Rico) | 72,932 | 64,341 | 71,347 | 78,699 | [3]78,859 |
| Uruguay | 818 | 726 | 442 | 368 | 330 |
| Venezuela | 5,375 | 5,988 | 4,899 | [r] [e]5,270 | 5,400 |
| Vietnam | 601 | [e]882 | 1,023 | [e]1,213 | 1,430 |
| Yemen (Sanaa) | 90 | 261 | 661 | 937 | 940 |
| Yugoslavia | 10,781 | 10,712 | 10,573 | 10,268 | 9,950 |
| Zaire | [r]545 | 596 | 565 | 583 | 530 |
| Zambia | 159 | 170 | 171 | 266 | 270 |
| Zimbabwe | 648 | 635 | (4) | (4) | -- |
| **Total** | [r]977,384 | [r]978,362 | 1,010,116 | 1,045,468 | 1,071,225 |

[e] Estimated. [p] Preliminary. [r] Revised. NA Not available.

[1] Table includes data available through July 8, 1986.

[2] Data are for the year beginning Mar. 21 of that stated.

[3] Reported figure.

[4] Revised to zero.

[5] Data are for the year ending June 30 of that stated.

[6] Revised to "Not available."

[7] Converted from officially reported data provided in terms of 94-pound cement bags.

[8] Excludes natural cement.

## TECHNOLOGY

**Cement.**—Martin Engineering Co. developed a new solution to an old problem, the use of compressed-air cannons to remove material buildup in cement kiln preheaters. The technology has been used successfully for many years on silos, bunkers, and hoppers. When a quick release valve is opened, an explosive charge of compressed air is expelled into the structure. The sudden powerful release of energy into the material causes it to break away from the walls and flow freely to the kiln. Benefits of the new technology were reduced work force, increased productivity, and decreased energy consumption through improved heat transfer and air-material flow.[5]

A new high-efficiency air separator, called the Sepax, was developed by F. L. Smidth and Co. A/S. The separator was successfully tested at the Sociedad Financiera y Minera S.A. cement plant in Malaga, Spain. Test results showed a 30% increase in output and a 20% reduction in energy consumption. The excellent performance was due primarily to effective dispersion of material fed from the mill to the riser duct. The separator was designed for easy integration with different plant configurations, not only for cement grinding but also for processing other materials.[6]

**Concrete.**—The Bureau of Mines summarized its research on sulfur construction materials as well as related research conducted by other Government organizations and the private sector. The research activity covers three areas, sulfur concretes, sulfur spray coatings, and sulfur-extended asphalt as a paving material.[7]

Fuller International Inc., Bethlehem, PA, a cement industry equipment supplier, announced the results of its worldwide search for ideas on new ways to use cement. A total of 540 entries were received from 24 countries. The first place award for the most original idea involved the use of portland cement for reducing sulfur emissions from fossil-fuel-burning powerplants. The second place, granted for the idea closest to implementation, involved the use of portland cement as an antistripping agent in asphalt mixes.[8]

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[1] Mineral specialist, Division of Industrial Minerals.

[2] U.S. Department of Commerce, International Trade Administration. Construction Review. V. 32, No. 1, Jan.-Feb. 1986, pp. 12-21.

[3] Engineering News-Record. ENR Materials Prices. V. 216, No. 2, Jan. 9, 1986, p. 40.

[4] Rock Products. Cement International. V. 89, No. 4, Apr. 1986, pp. 39-75.

[5] Brown, B. E., and L. J. Goldbeck. Using Air Cannons on Cement Kiln Preheaters. Pit & Quarry, v. 78, No. 2, Aug. 1985, pp. 95-106.

[6] Joergensen, W. S. Develop High Efficiency Air Separator for Grinding Systems. Pit & Quarry, v. 78, No. 1, 1985, pp. CR36-CR40.

[7] McBee, W. C., T. A. Sullivan, and H. L. Fike. Sulfur Construction Materials. BuMines B. 678, 1985, p. 31.

[8] Fuller International Inc. Quest: The Worldwide Search for New Uses of Cement. Nov. 1985, p. 30.

# Chromium

## By John F. Papp[1]

In 1985, reported chromium consumption was 292,766 short tons, a 7% decrease from that of 1984. The reported consumption of chromium by the metallurgical and refractory industries decreased, whereas that of the chemical industry increased. Metallurgical industry production includes ferrochromium preduced as part of the National Defense Stockpile (NDS) conversion program. Imports of chromite increased, those of ferrochromium decreased.

**Domestic Data Coverage.**—Domestic consumption of chromite by the primary consuming industries—metallurgical, refractory, and chemical—are developed by the Bureau of Mines by means of the voluntary monthly "Chromite Ores and Chromium Products" survey. The companies listed in table 3 by industry accounted for 100% of the chromite consumption data by industry in table 5. In 1985, 83% of the metallurgical companies, 100% of the refractory companies, and 67% of the chemical companies reported chromite consumption. Consumption was estimated for the remaining 17% of the metallurgical industry and 33% of the chemical industry.

Domestic production data for chromium ferroalloys and metal are developed by the Bureau of Mines by means of two separate voluntary surveys. These two surveys are the monthly "Chromite Ores and Chromium Products" and the annual "Ferroalloys." Production by the six metallurgical industry companies listed in table 3 represented 100% of domestic production shown in table 4. Eighty-three percent of those companies responded to both surveys. Production for the remaining 17% was estimated.

**Table 1.—Salient chromium statistics**

(Thousand short tons, gross weight)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| CHROMITE | | | | | |
| United States: | | | | | |
| Exports | 71 | 8 | 11 | 55 | 101 |
| Reexports | 67 | 57 | 5 | 4 | 4 |
| Imports for consumption | 898 | 507 | 190 | 305 | 414 |
| Consumption | 889 | 558 | 320 | 512 | 560 |
| Stocks, Dec. 31: Consumer | 728 | [r]546 | [r]456 | 327 | 300 |
| World: Production | [r]10,018 | [r]9,026 | 8,829 | [p]10,312 | [e]10,951 |
| CHROMIUM FERROALLOYS[1] | | | | | |
| United States: | | | | | |
| Production[2] | 226 | 119 | 36 | 95 | 110 |
| Exports | 14 | 5 | 4 | 15 | 10 |
| Reexports | 1 | ([3]) | 2 | 1 | 1 |
| Imports for consumption | 440 | 148 | 282 | 434 | 335 |
| Consumption | 423 | 262 | 388 | 395 | 369 |
| Stocks, Dec. 31: Consumer | 54 | 26 | 26 | 25 | 31 |
| World: Production | [r]3,060 | [r]2,612 | 2,774 | [p]3,244 | [e]3,247 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] High- and low-carbon ferrochromium plus ferrochromium-silicon.

[2] Includes chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.

[3] Less than 1/2 unit.

**Legislation and Government Programs.**—In accordance with the President's November 1982 directive, the General Services Administration (GSA) continued to upgrade NDS chromium ore to high-carbon ferrochromium. The GSA reported conversion of 125,628 tons of chromium ore to 50,254 tons of ferrochromium at a cost of $22.7 million in calendar year 1984 and 137,015 tons of chromium ore to 49,463 tons of ferrochromium at a cost of $22.5 million in calendar year 1985. The GSA exercised its contractual option to extend NDS upgrading into its third year.

The U.S. Congress, Office of Technology Assessment (OTA), completed a study on technologies to reduce U.S. vulnerability to chromium supply disruption. Based on criticality and extent of use, and vulnerability of supply, OTA found chromium to be a first-tier strategic material. Within the technological categories—mineral production and metal processing, conservation, and substitution—OTA identified and discussed potential benefits of and barriers to vulnerability reduction.[2] The OTA also examined the use of and potential substitution for chromium in superalloys used in defense applications.[3]

The Bureau of Mines published a directory of 45 domestic and 84 foreign chromium properties and deposits.[4] Nonconfidential data on location, reserves and resources, geology, mine and beneficiation systems, and operations were included. The Bureau analyzed the chromium industry of the U.S.S.R., a major world producer and exporter of chromite ore. The report found the U.S.S.R.'s reserves to be adequate to meet its long-term needs. It also found that both production growth and experts have declined in recent years. Salient characteristics of the Soviet chromium raw material base, mining and processing facilities, foreign trade, policies and programs, and future outlook were described.[5] The Bureau reviewed technological alternatives for the conservation of chromium. The review found that present U.S. chromium consumption could be reduced by about one-third by using available technology. Such technology could be used to substitute alternative materials and processes, to recover and recycle waste chromium, and to design for greater chromium efficiency.[6]

The Environmental Protection Agency (EPA) issued final water pollution rules requiring the petroleum refining industry to more stringently control total chromium and hexavalent chromium contained in waste water and storm water runoff from refinery property.[7] The EPA estimated that the new final rule would reduce allowable total chromium discharge by 286,000 pounds per year, and hexavalent chromium by 19,300 pounds per year. In another report, the EPA found chromium trichloride to be an acutely toxic chemical.[8]

The U.S. Department of Commerce and the Federal Emergency Management Agency published new NDS Specifications for chemical industry chromite ore and for chromium metal and new NDS Special Instructions for chromium metal.

The U.S. Department of Energy (DOE), as part of the National Uranium Resources Evaluation (NURE) program, geochemically assayed for chromium in streamwater and stream-sediment samples from throughout the continental United States and Alaska. The DOE's NURE assay data were put into a computer data base. Researchers located an outcrop of chromium-bearing rock by analyzing the NURE data base.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. Based on a study of the 42 most significant of 62 stockpiled materials, 6 of the 42 materials were allocated to tier I. Chromium was included in tier I. The current NDS chromium goal is 1.353 million tons contained chromium in the form of chemical- and metallurgical-grade ore, low- and high-carbon ferrochromium, ferrochromium-silicon, and chromium metal. Current NDS inventory is 1.276 million tons contained chromium. The proposed restructuring allocates 199,000 tons contained chromium to tier I and 594,000 tons contained chromium to tier II without specifying distribution among the numerous chromium material categories. These proposed allocations eliminate 77,000 tons contained chromium of unmet goals and 483,000 tons contained chromium of current inventory. At yearend, this proposal was under consideration by the Congress. The

Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

**Table 2.—U.S. Government stockpile goals and yearend inventories for chromium in 1985**

(Thousand short tons, gross weight)

| Material | Stockpile goals | Physical inventory | | |
|---|---|---|---|---|
| | | Stockpile-grade | Nonstockpile-grade | Total |
| Chromite, metallurgical | 3,200 | 1,943 | 313 | 2,256 |
| Chromite, chemical | 675 | 242 | -- | 242 |
| Chromite, refractory | 850 | 391 | -- | 391 |
| High-carbon ferrochromium | 185 | 452 | 1 | 453 |
| Low-carbon ferrochromium | 75 | 300 | 19 | 319 |
| Ferrochromium-silicon | 90 | 57 | 1 | 58 |
| Chromium metal | 20 | 4 | -- | 4 |

Source: Federal Emergency Management Agency.

## DOMESTIC PRODUCTION

The major marketplace products of chromium are chromium ore, alloys, chemicals, and metal. In 1985, the United States produced chromium alloys, chemicals, and metal from imported chromium ore. No chromium ore was mined domestically.

Domestic chromium resources are being developed by California Nickel Corp. and Interstrat Resources Inc. California Nickel awaited Forest Service, U.S. Department of Agriculture, approval of an environmental impact statement submitted in 1984. Chromium would be a byproduct of nickel and cobalt production at the Gasquet Mountain property. Interstrat financed a feasibility study for the Pine Flat Mountain claim, which it co-owns with Coastal Mining Co., a subsidiary of M. A. Hanna Co. Chromium ore would be a byproduct of nickel at the Pine Flat Mountain Claim.

The Minnesota Department of Natural Resources (DNR) announced the discovery of chromium mineralization in the Duluth Gabbro Complex in northeastern Minnesota. DNR identified a 7-foot layer of rock at a depth of 2,400 feet to have a 3.9% chromium content. This material, although not of commercial grade, encourages DNR to investigate further.

Allied Corp. closed its chromium chemicals plant at Baltimore, MD. The Baltimore plant started production in 1845 as a producer of potassium bichromate. At closure, the plant had a production capacity of 65,000 tons per year of hydrous sodium bichromate.

Foote Mineral Co. closed its Graham, WV, plant. Elkem Metals Co. experienced a 1-month strike at its Marietta, OH, plant. Satra Concentrates bought slags and equipment from Satralloy Inc. in Beverly, OH. Satralloy has not operated the ferrochromium plant since 1982. Satra Concentrates expects to produce about 175,000 tons of high-carbon and 1,000,000 tons of low-carbon chromium concentrates from slags during the time period 1985-89.

Chem-Lig International started construction of a plant at Port Allen, LA. The plant was to produce chromium and iron-chromium lignosulfonates for drilling fluids and other applications.

### Table 3.—Principal producers of chromium products in 1985, by industry

| Industry and company | Plant |
|---|---|
| **Metallurgical:** | |
| Elkem AS, Elkem Metals Co | Marietta, OH, and Alloy, WV. |
| Foote Mineral Co | Graham, WV. |
| Macalloy Inc | Charleston, SC. |
| Metallurg Inc., Shieldalloy Corp | Newfield, NJ. |
| Moore McCormack Resources Inc., Globe Metallurgical Inc | Beverly, OH. |
| SKW Alloys Inc | Calvert City, KY, and Niagara Falls, NY. |
| **Refractory:** | |
| Basic Inc | Maple Grove, OH. |
| Corhart Refractories Co. Inc | Pascagoula, MS. |
| Davis Refractories Inc | Jackson, OH. |
| General Refractories Co | Lehi, UT. |
| Harbison-Walker Refractories, a division of Dresser Industries Inc | Hammond, IN, and Baltimore, MD. |
| Kaiser Aluminum & Chemical Corp | Plymouth Meeting, PA. |
| National Refractories & Minerals Corp | Moss Landing, CA, and Columbiana, OH. |
| North American Refractories Co. Ltd | Womelsdorf, PA. |
| **Chemical:** | |
| Allied Chemical Corp | Baltimore, MD. |
| American Chrome & Chemicals Inc | Corpus Christi, TX. |
| Diamond Shamrock Corp., Diamond Shamrock Chemicals Co | Castle Hayne, NC. |

### Table 4.—Production, shipments, and stocks of chromium ferroalloys and chromium metal in the United States

(Short tons)

| Material | Net production | | Net shipments | Producer stocks, Dec. 31 |
|---|---|---|---|---|
| | Gross weight | Chromium content | | |
| 1984: | | | | |
| Low-carbon ferrochromium<br>High-carbon ferrochromium<br>Chromium concentrate | 79,515 | 50,919 | 110,389 | 16,256 |
| Ferrochromium-silicon<br>Chromium metal<br>Other[1] | 15,885 | 8,324 | 10,383 | 8,282 |
| Total | 95,400 | 59,243 | 120,772 | 24,538 |
| 1985: | | | | |
| Low-carbon ferrochromium<br>High-carbon ferrochromium<br>Chromium concentrate | 99,027 | 62,556 | 94,470 | 18,775 |
| Ferrochromium-silicon<br>Chromium metal<br>Other[1] | 10,536 | 5,637 | 14,002 | 4,786 |
| Total | 109,563 | 68,193 | 108,472 | 23,561 |

[1] Includes exothermic chromium additives and other miscellaneous chromium alloys.

## CONSUMPTION AND USES

Domestic consumption of chromite ore and concentrate was 560,421 tons in 1985. Of the total chromite consumed, the metallurgical industry used 48.7%; the chemical industry, 39.7%; and the refractory industry, 11.6%. Most of the chromite consumed and ferrochromium produced by the metallurgical industry was part of the NDS conversion program. (See "Legislation and Government Programs" section of this chapter).

Chromium has a wide range of uses in the three primary consumer groups. In the metallurgical industry, its principal use in 1985 was in stainless steel. Of the 376,452 tons of chromium ferroalloys, metal, and other chromium-containing materials reported consumed, stainless steel accounted for 78%; full-alloy steel, 9%; superalloys, 3%; and other end uses, 10%. Chromium ferroalloys, metal, and other chromium material consumption decreased 6% compared with that of 1984.

The primary use of chromium in the refractory industry was in the form of chromite to make refractory bricks to line metallurgical furnaces. Chromite consumption by the refractory industry decreased 33% compared with that of 1984.

The chemical industry consumed chromite for manufacturing chromates, chromic acid, and pigments. Sodium and potassium chromate and bichromate are the materials from which a wide range of chromium chemicals are made. Chromite consumption by the chemical industry in 1985 increased 18% compared with that of 1984.

**Table 5.—Consumption of chromite and tenor of ore used by primary consumer groups in the United States**

| Year | Metallurgical industry | | Refractory industry | | Chemical industry | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Gross weight (short tons) | Average $Cr_2O_3$ (percent) | Gross weight (short tons) | Average $Cr_2O_3$ (percent) | Gross weight (short tons) | Average $Cr_2O_3$ (percent) | Gross weight (short tons) | Average $Cr_2O_3$ (percent) |
| 1981 | 503,051 | 35.7 | 147,853 | 37.3 | 238,465 | 42.6 | 889,369 | 37.9 |
| 1982 | 283,481 | 35.2 | 79,760 | 36.4 | 194,935 | 44.9 | 558,176 | 38.9 |
| 1983 | 64,310 | 39.3 | 72,050 | 36.9 | 183,611 | 44.9 | 319,971 | 42.0 |
| 1984 | 225,727 | 43.5 | 97,469 | 37.4 | 188,960 | 44.8 | 512,156 | 42.8 |
| 1985 | 272,885 | 38.5 | 65,245 | 38.1 | 222,291 | 45.3 | 560,421 | 41.2 |

**Table 6.—U.S. consumption of chromium ferroalloys and metal in 1985, by end use**

(Short tons, gross weight)

| End use | Ferrochromium | | Ferrochromium silicon | Other | Total |
|---|---|---|---|---|---|
| | Low-carbon ferrochromium | High-carbon ferrochromium | | | |
| Steel: | | | | | |
| Carbon | 3,156 | 3,867 | W | W | 7,023 |
| Stainless and heat-resisting | 9,797 | 275,951 | 6,271 | 583 | 292,602 |
| Full-alloy | 6,091 | 26,570 | 1,685 | 83 | 34,429 |
| High-strength, low-alloy and electric | 2,221 | 2,075 | W | W | 4,296 |
| Tool | 989 | 3,032 | 250 | -- | 4,221 |
| Cast irons | 536 | 5,708 | W | W | 6,244 |
| Superalloys | 4,236 | 3,587 | 65 | 3,236 | 11,124 |
| Welding materials[1] | 428 | 646 | -- | 74 | 1,148 |
| Other alloys[2] | 416 | 166 | W | 2,012 | 2,594 |
| Miscellaneous and unspecified | 102 | 24 | 11,462 | 1,183 | 12,771 |
| Total | 27,922 | 321,626 | 19,733 | [3]7,171 | 376,452 |
| Chromium content | 19,108 | 174,999 | 7,135 | 5,619 | 206,861 |
| Stocks, Dec. 31 | 5,482 | 24,115 | 1,289 | [4]1,280 | 32,166 |

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

[1] Includes structural and hard-facing welding material.

[2] Includes magnetic and nonferrous alloys.

[3] Includes 4,341 tons of chromium metal.

[4] Includes 535 tons of chromium metal.

## STOCKS

Reported consumer stocks of chromite declined from 327,321 tons in 1984 to 300,187 tons in 1985. Metallurgical industry stocks increased, whereas chemical and refractory industry stocks declined. Producer stocks of chromium ferroalloys, metal, and other materials declined from 24,538 tons in 1984 to 23,561 tons in 1985. Consumer stocks increased from 26,302 tons in 1984 to 32,166 tons in 1985. At the 1985 annual rate of chromium ferroalloy and metal consumption, producer plus consumer stocks represented a 1.4-month supply.

### Table 7.—U.S. consumer stocks of chromite, December 31, by industry

(Short tons, gross weight)

| Industry | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Metallurgical | 229,800 | 119,540 | 140,324 | 24,442 | 44,361 |
| Refractory | 128,210 | 113,233 | 75,832 | 69,619 | 48,635 |
| Chemical | 370,463 | 312,808 | 239,420 | 233,260 | 207,191 |
| Total | 728,473 | 545,581 | 455,576 | 327,321 | 300,187 |

### Table 8.—U.S. consumer stocks of chromium ferroalloys and metal, December 31, by product

(Short tons, gross weight)

| Product | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Low-carbon ferrochromium | 5,198 | 3,459 | 3,474 | 3,375 | 5,482 |
| High-carbon ferrochromium | 46,601 | 21,793 | 20,948 | 19,946 | 24,115 |
| Ferrochromium-silicon | 1,801 | 1,237 | 1,294 | 1,422 | 1,289 |
| Other[1] | 2,468 | 2,593 | 954 | 1,559 | 1,280 |
| Total | 56,068 | 29,082 | 26,670 | 26,302 | 32,166 |

[1] Includes chromium briquets, chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.

## PRICES

The price of South African chromite ore decreased, whereas that of Turkish chromite increased. The published price of South African Transvaal chromite, 44% $Cr_2O_3$, no specific chromium-to-iron ratio, decreased from a range of $48 to $52 per metric ton to a range of $40 to $42 per metric ton, f.o.b. South African ports. The published price of Turkish chromite increased from $110 per metric ton to $125 per metric ton, f.o.b. Turkish ports.

The price of domestic chromium ferroalloys and metal remained unchanged. The published price of imported high-carbon ferrochromium containing 50% to 55% chromium decreased from a range of 43 to 45 cents per pound to a range of 43 to 44.5 cents per pound in January. It then increased to a range of 43 to 45 cents per pound in September and declined to a range of 42.5 to 44 cents per pound in October. The published price of imported high-carbon ferrochromium containing 60% to 65% chromium declined from a range of 45 to 46 cents per pound to a range of 44.5 to 46 cents per pound in January. It then increased to a range of 45.5 to 46.5 cents per pound in February, increased again to a range of 46.5 to 48 cents per pound in June, and then decreased to a range of 46 to 47 cents per pound in October. The published price of imported low-carbon ferrochromium increased from a range of 87 to 89 cents per pound to a range of 88 to 89.5 cents per pound in June. It then decreased to a range of 86 to 87 cents per pound in October.

**Table 9.—Price quotations for chromium materials at beginning and end of 1985**

| Material | January | December |
|---|---|---|
| | Cents per pound of chromium | |
| U.S. charge chromium (50% to 55% chromium) | (1) | (1) |
| Imported charge chromium (50% to 55% chromium) | 43-45 | 42.5-44 |
| Imported charge chromium (60% to 65% chromium) | 45-46 | 46-47 |
| U.S. charge chromium (66% to 70% chromium) | 54 | 54 |
| U.S. low-carbon ferrochromium (0.025% carbon) | 100 | 100 |
| U.S. low-carbon ferrochromium (0.05% carbon) | 95 | 95 |
| Imported low-carbon ferrochromium (0.05% carbon) | 89-95 | 86-87 |
| Simplex (low-carbon ferrochromium) | 100 | 100 |
| | Cents per pound of product | |
| Electrolytic chromium metal | 375 | 375 |
| Ferrochromium-silicon | [r]38.6 | 38.6 |

[r]Revised.
[1]Price listing suspended.

Source: Metals Week.

## FOREIGN TRADE

Exports of chromium materials from the United States included chromite ore, chromium metal, ferroalloys, chemicals, and pigments. Exports of chromite ore and concentrate increased 84% in 1985. Exports of all other chromium materials decreased.

Imports of chromium materials included chromium metal, ferrochromium-silicon, chemicals, and pigments. Imports of chromium metal and ferrochromium-silicon decreased 16% and 50%, respectively, in 1985. Of the chromium chemicals, imports of chromic acid, potassium chromate and dichromate, and sodium chromate and dichromate increased 100%, 15%, and 135%, respectively. Chromium carbide imports decreased 32%.

**Table 10.—U.S. exports and reexports of chromite ores and concentrates**

| Year | Exports | | Reexports | |
|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1981 | 70,672 | $5,893 | 66,566 | $9,575 |
| 1982 | 8,165 | 1,574 | 56,830 | 9,172 |
| 1983 | 11,032 | 1,874 | 4,561 | 1,350 |
| 1984 | 54,928 | 2,957 | 3,855 | 864 |
| 1985 | 100,810 | 4,600 | 3,676 | 670 |

Source: Bureau of the Census.

## Table 11.—U.S. exports of chromium materials, by type

| Type | 1983 | 1984 | 1985 | | Principal destinations, 1985 |
|---|---|---|---|---|---|
| | Quantity (short tons) | Quantity (short tons) | Quantity (short tons) | Value (thousands) | |
| Chromite ore and concentrate | 11,032 | 54,928 | 100,810 | $4,600 | Sweden (67%); Republic of Germany (30%). |
| Metal and alloys: | | | | | |
| Chromium metal[1] | 238 | 259 | 222 | 2,964 | Japan (21%); United Kingdom (32%); Canada (16%). |
| Chromium ferroalloys | [2]4,247 | [3]15,388 | [4]10,262 | 7,688 | Federal Republic of Germany (51%); Canada (32%). |
| Chemicals: | | | | | |
| Chromic acid | 3,927 | 5,672 | 3,881 | 5,582 | Japan (24%); Canada (23%); Republic of Korea (16%). |
| Potassium chromate and dichromate | 11 | 72 | 71 | 94 | Canada (58%); Australia (10%). |
| Sodium chromate and dichromate | 14,174 | 18,321 | 9,726 | 5,679 | Republic of Korea (23%); Canada (18%); China (17%); Colombia (14%). |
| Pigments | 2,555 | 2,062 | 1,928 | 6,438 | Canada (29%); Federal Republic of Germany (17%); Japan (11%). |

[1] Wrought and unwrought and waste and scrap.
[2] Contained 2,589 tons of chromium.
[3] Contained 9,996 tons of chromium.
[4] Contained 6,277 tons of chromium.

Source: Bureau of the Census.

## Table 12.—U.S. imports of selected chromium materials, by type

| Type | 1983 | 1984 | 1985 | | Principal sources, 1985 |
|---|---|---|---|---|---|
| | Quantity (short tons) | Quantity (short tons) | Quantity (short tons) | Value (thousands) | |
| Metal and alloys: | | | | | |
| Chromium metal[1] | 3,359 | 4,677 | 3,954 | $19,615 | United Kingdom (44%); Japan (32%); China (11%); France (10%). |
| Ferrochromium-silicon | [2]1,438 | [3]7,942 | [4]3,940 | 2,085 | Zimbabwe (98%); Italy (2%). |
| Chemicals: | | | | | |
| Chromic acid | 3,267 | 2,456 | 4,905 | 6,965 | Italy (28%); Federal Republic of Germany (28%); Netherlands (16%); United Kingdom (14%). |
| Chromium carbide | 237 | 181 | 123 | 897 | Federal Republic of Germany (54%); United Kingdom (33%); Japan (12%). |
| Potassium chromate and dichromate | 347 | 554 | 639 | 676 | Federal Republic of Germany (35%); United Kingdom (33%); U.S.S.R. (18%). |
| Sodium chromate and dichromate | 8,933 | 4,617 | 10,836 | 6,380 | United Kingdom (36%); Italy (21%); Turkey (13%); Republic of South Africa (12%). |
| Pigments: | | | | | |
| Chrome green | 21 | 53 | 202 | 126 | Mexico (73%); Canada (15%). |
| Chrome yellow | 1,933 | 2,560 | 3,187 | 4,480 | Canada (59%); Federal Republic of Germany (17%); United Kingdom (13%). |
| Chrome oxide green | 1,997 | 1,999 | 1,616 | 3,168 | Federal Republic of Germany (51%); Japan (29%); Romania (9%). |
| Hydrated chromium oxide green | 2 | 18 | 13 | 79 | Belgium (85%); Italy (15%). |
| Molybdenum orange | 738 | 1,013 | 1,077 | 2,278 | Canada (70%); Federal Republic of Germany (13%). |
| Strontium chromate | 165 | 197 | 431 | 892 | Federal Republic of Germany (30%); France (24%), Spain (22%); Belgium (18%). |
| Zinc yellow | 1,381 | 1,186 | 1,731 | 2,121 | Norway (44%); Federal Republic of Germany (18%); Canada (16%); Hungary (16%). |

[1] Wrought and unwrought and waste and scrap.
[2] Contained 579 tons of chromium.
[3] Contained 3,032 tons of chromium.
[4] Contained 1,493 tons of chromium.

Source: Bureau of the Census.

## Table 13.—U.S. import duties for chromium-containing materials

| Item | TSUS No. | Most favored nation (MFN) | | Non-MFN |
|---|---|---|---|---|
| | | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Ore: Chrome ore and concentrate | 601.15 | Free | No target duty | Free. |
| Metal and alloys: | | | | |
| Low-carbon ferrochromium | 606.22 | 3.4% ad valorem | 3.1% ad valorem | 30% ad valorem. |
| High-carbon ferrochromium | 606.24 | 1.9% ad valorem | No target duty | 7.5% ad valorem. |
| Ferrosilicon chromium | 606.42 | 10% ad valorem | 10% ad valorem | 25% ad valorem. |
| Chrome metal[1] | 632.18 | 4% ad valorem | 3.7% ad valorem | 30% ad valorem. |
| Chemicals: | | | | |
| Potassium chromate and dichromate | 420.08 | 1.6% ad valorem | 1.5% ad valorem | 8.5% ad valorem. |
| Sodium chromate and dichromate | 420.98 | 2.5% ad valorem | 2.4% ad valorem | 8.5% ad valorem. |
| Chromium carbide | 422.92 | 4.7% ad valorem | 4.2% ad valorem | 25% ad valorem. |
| Chromic acid | 423.0092 | 4% ad valorem | 3.7% ad valorem | Do. |
| Pigments: | | | | |
| Chrome green | 473.10 | 4% ad valorem | No target duty | Do. |
| Chrome yellow | 473.12 | do | do | Do. |
| Chromium oxide green | 473.14 | do | 3.7% ad valorem | Do. |
| Hydrated chromium oxide green | 473.16 | do | do | Do. |
| Molybdenum orange | 473.18 | do | No target duty | Do. |
| Strontium chromate | 473.19 | do | 3.7% ad valorem | Do. |
| Zinc yellow | 473.20 | do | No target duty | Do. |

[1] Includes wrought, unwrought, waste and scrap chromium metal.

## Table 14.—U.S. imports for consumption of chromite, by country

| Country | Not more than 40% $Cr_2O_3$ |  |  | More than 40% but less than 46% $Cr_2O_3$ |  |  | 46% or more $Cr_2O_3$ |  |  | Total[1] |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Gross weight (short tons) | $Cr_2O_3$ content (short tons) | Value (thousands) | Gross weight (short tons) | $Cr_2O_3$ content (short tons) | Value (thousands) | Gross weight (short tons) | $Cr_2O_3$ content (short tons) | Value (thousands) | Gross weight (short tons) | $Cr_2O_3$ content (short tons) | Value (thousands) |
| 1984: |  |  |  |  |  |  |  |  |  |  |  |  |
| Canada | 5,929 | 2,248 | $320 | 30 | 12 | $2 | 2 | 1 | ([2]) | 5,961 | 2,256 | $322 |
| Finland | -- | -- | -- | 11,228 | 4,940 | 535 | -- | -- | -- | 11,228 | 4,940 | 535 |
| New Caledonia | -- | -- | -- | -- | -- | -- | 3,472 | 1,944 | $357 | 3,472 | 1,944 | 357 |
| Philippines | 45,293 | 15,083 | 4,154 | -- | -- | -- | 3,196 | 1,901 | 350 | 48,489 | 16,984 | 4,504 |
| South Africa, Republic of | 5,441 | 2,104 | 372 | 109,705 | 48,459 | 4,121 | 120,284 | 57,689 | 5,265 | 235,430 | 108,252 | 9,758 |
| Total[1] | 56,668 | 19,380 | 4,846 | 120,963 | 53,412 | 4,659 | 126,955 | 61,585 | 5,972 | 304,580 | 134,327 | 15,477 |
| 1985: |  |  |  |  |  |  |  |  |  |  |  |  |
| Albania | 15,673 | 5,396 | 485 | 2,315 | 972 | 182 | -- | -- | -- | 17,988 | 6,368 | 617 |
| Canada | -- | -- | -- | 4 | 2 | 1 | -- | -- | -- | 4 | 2 | 1 |
| Finland | -- | -- | -- | 22,838 | 10,330 | 1,140 | -- | -- | -- | 22,838 | 10,330 | 1,140 |
| Japan | -- | -- | -- | 48 | 19 | 4 | -- | -- | -- | 48 | 19 | 4 |
| Philippines | 41,399 | 12,917 | 3,179 | -- | -- | -- | -- | -- | -- | 41,399 | 12,917 | 3,179 |
| South Africa, Republic of | 32,533 | 12,951 | 1,266 | 142,474 | 63,228 | 6,135 | 126,182 | 59,094 | 5,854 | 301,189 | 135,273 | 13,255 |
| Turkey | 30,905 | 11,282 | 1,974 | -- | -- | -- | -- | -- | -- | 30,905 | 11,282 | 1,974 |
| Total[1] | 120,510 | 42,545 | 6,904 | 167,679 | 74,554 | 7,412 | 126,182 | 59,094 | 5,854 | 414,371 | 176,191 | 20,170 |

[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.

Source: Bureau of the Census.

### Table 15.—U.S. imports for consumption of ferrochromium, by country

| Country | Low-carbon ferrochromium (less than 3% carbon) | | | High-carbon ferrochromium (3% or more carbon) | | |
|---|---|---|---|---|---|---|
| | Gross weight (short tons) | Chromium content (short tons) | Value (thousands) | Gross weight (short tons) | Chromium content (short tons) | Value (thousands) |
| 1984: | | | | | | |
| Brazil | -- | -- | -- | 13,062 | 7,055 | $4,616 |
| Canada | -- | -- | -- | 23 | 15 | 10 |
| France | 19 | 14 | $25 | 21 | 18 | 4 |
| Germany, Federal Republic of | 5,023 | 3,603 | 5,072 | 39 | 26 | 52 |
| India | -- | -- | -- | 3,420 | 2,356 | 1,649 |
| Italy | 710 | 531 | 868 | 4,956 | 3,023 | 1,968 |
| Japan | 60 | 39 | 65 | 36 | 25 | 31 |
| Norway | 51 | 33 | 74 | -- | -- | -- |
| Philippines | -- | -- | -- | 5,423 | 3,428 | 2,434 |
| South Africa, Republic of | 4,997 | 3,066 | 4,018 | 257,919 | 136,199 | 97,010 |
| Spain | -- | -- | -- | 925 | 632 | 429 |
| Sweden | 4,325 | 3,163 | 4,778 | 1,101 | 689 | 480 |
| Turkey | 1,873 | 1,256 | 1,613 | 47,907 | 29,234 | 19,648 |
| Yugoslavia | -- | -- | -- | 27,675 | 17,925 | 18,420 |
| Zimbabwe | 8,074 | 5,531 | 6,885 | 38,170 | 24,868 | 18,302 |
| Total[1] | 25,182 | 17,236 | 23,897 | 400,677 | 225,487 | 160,054 |
| 1985: | | | | | | |
| Brazil | -- | -- | -- | 10,362 | 5,589 | 3,860 |
| Canada | -- | -- | -- | 145 | 99 | 58 |
| Finland | -- | -- | -- | 8,851 | 4,658 | 3,534 |
| Germany, Federal Republic of | 4,445 | 3,178 | 4,803 | 1,240 | 778 | 632 |
| Greece | -- | -- | -- | 4,082 | 2,489 | 2,238 |
| Italy | 169 | 123 | 206 | -- | -- | -- |
| Japan | 513 | 337 | 541 | 602 | 398 | 589 |
| Netherlands | 78 | 56 | 86 | 772 | 344 | 24 |
| Philippines | -- | -- | -- | 6,483 | 3,896 | 2,844 |
| South Africa, Republic of | 5,151 | 3,062 | 3,889 | 198,320 | 105,178 | 78,427 |
| Sweden | 7,004 | 4,730 | 7,063 | -- | -- | -- |
| Turkey | 4,094 | 2,795 | 4,135 | 26,932 | 17,340 | 13,152 |
| Yugoslavia | -- | -- | -- | 13,998 | 9,065 | 7,155 |
| Zimbabwe | 4,781 | 3,244 | 4,253 | 33,043 | 21,752 | 19,058 |
| Total[1] | 26,236 | 17,525 | 24,976 | 304,829 | 171,587 | 131,570 |

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

World chromite production increased to 11 million tons, from 10 million tons in 1984. Ferrochromium production increased to 3,160,000 tons from 3,155,000 tons in 1984.

Chromite resource investigations were reported in Australia, Brazil, Pakistan, and Turkey. Ferrochromium production facilities started production in Finland and India. Ferrochromium production capacity was being developed in India, the Republic of South Africa, Sweden, and Turkey.

France and the United Kingdom were disposing of their stockpiles. Japan was building its stockpile. The Republic of Korea announced its decision to build a stockpile.

Finland and the Republic of South Africa are the two major world chromium producers integrated from chromite ore production through stainless steel marketing.

**Australia.**—Australia Mining N.L. made an agreement with Ascot Holdings Pty. Ltd. to explore the Omega Prospect in Western Australia, about 350 kilometers north-northeast of Geraldton. Previous exploration preliminarily identified a 1,600-meter strike length. Two 0.5-meter drill holes yielded material grading 7% and 8.8% chromium content.

**Brazil.**—The Brazilian Mines and Energy Ministry located a chromite deposit about 1.5 kilometers from the Mineração Vale do Jacurici S.A. operation in Bahia State. A second chromite deposit was located by Docegeo, the Brazilian state mineral exploration company, in Pará State, about 15 kilometers from the famous Serra Pelada gold mine. Brazil produces chromite for domestic consumption, ferrochromium for domestic use and export, and stainless steel for domestic use.

**European Economic Community (EEC).**—The EEC doubled its 1985 duty-free ferrochromium quota from 228,000 tons to 456,000 tons, including ferrochromium containing not less than 4% carbon, from 8,000 to 15,000 tons, and that containing not less than 6% carbon, from 200,000 to 400,000 tons.

The EEC set its 1986 duty-free quota at 19,000 tons for ferrochromium containing not less than 4% carbon, and 200,000 tons for ferrochromium containing not less than 6% carbon.

**Finland.**—In 1985, Outokumpu Oy started production, at its Tornio Works, with a 75-megavolt-ampere furnace having a high-carbon ferrochromium production capacity of from 100,000 to 120,000 tons per year. The new furnace was constructed in about 15 months between 1983 and 1985 at a cost of about $35 million. The new furnace is part of a process that uses hot gases resulting from smelting to preheat the furnace feed. Outokumpu started production of high-carbon ferrochromium in 1968 with a 35-megavolt-ampere furnace of 60,000-ton-per-year production capacity. Finland produced chromite, ferrochromium, and stainless steel for world markets.

**Greece.**—Hellenic Ferroalloy S.A. announced its intention to increase production capacity from the present 45,000 tons per year to 100,000 tons per year. The capacity expansion was planned to be achieved by adding a 36-megavolt-ampere furnace to its present 20-megavolt-ampere furnace.

**India.**—Orissa Mining Corp. Ltd. started operation of its ferrochromium plant in Bamnipal, Orissa. The plant had one 35-megavolt-ampere furnace with about 50,000 tons per year of production capacity.

Indian Charge Chrome Ltd., a subsidiary of Indian Metals and Ferro Alloys Ltd., contracted for the construction of a coal-fired powerplant to serve its presently operating ferrochromium plant at Therubali and its plant under construction at Choudhar.

The Minister for Steel and Mines reported India's detailed mineral land mapping to be over one-half completed. Chromite mineral reserves were set at 148 million tons. The Geological Survey of India reported chromite resources of Orissa to be 144 million tons.

**Japan.**—Japan announced the decision to reduce its import duty on chromium ferroalloys. The reduced duties were to become effective in 1986. The duty on ferrochromium was to be reduced from 8% ad valorem to 7.2% ad valorem. The duty on ferrochromium-silicon was to be reduced from 3.7% ad valorem to 3% ad valorem.

Japan offered its ferrochromium industry financial support in exchange for the reduction of ferrochromium production capacity. The offer was made under Japan's industrial restructuring law. The ferrochromium industry was to reduce its capacity by about 10% of its 632,000 tons of installed capacity, to be achieved by March 31, 1987. Financial support was to be made through personal-property-tax-payment exemption.

Japan added 7,910 tons of high-carbon ferrochromium to its stockpile, of which 3,296 tons was added to the national stockpile, 3,296 tons to the joint Government-private stockpile, and 1,318 tons to the private stockpile. The material added represented about 4.8 days worth of consumption by the Japanese industry, making Japan's stockpile equivalent to about 16.8 days of consumption. Japan planned to add a 4.8-day supply in the 1985 fiscal year (April 1985 to March 1986).

**Korea, Republic of.**—The Republic of Korea announced its decision to stockpile 1,300 tons of ferrochromium by the end of 1985.

**Oman.**—Oman Mining Co. (OMC) reported confirmation of reserves of 2 million tons of chromite. OMC had a chromite production capacity of about 20,000 tons per year and produced about 7,000 tons in 1984. OMC considered the construction of a crusher and smelter to process its ore into ferrochromium. A decision to construct a plant would be based primarily on adequacy of chromite ore reserves and availability of investment capital.

**Pakistan.**—The Geological Survey of Pakistan was conducting exploratory studies of chromite deposits in the Lasbele District and in Malakand. The Pakistan Development Corp. and Al-Ghurair Enterprises, of United Arab Emirates, agreed to jointly develop a chrome-magnesite refractory brick factory.

**South Africa, Republic of.**—Union Carbide Corp. negotiated the sale of its interest in Tubatse Ferrochrome (Pty.) Ltd., Jagdlust Chrome Co. (Pty.) Ltd., Chrometco

Minerals Pty. Ltd., and Chrome Corp. (South Africa) Pty. Ltd. to General Mining Union Corp. Ltd. (Gencor). The sale was to take place in January 1986. Gencor owns South African Manganese Amcor Ltd. (Samancor).

Samancor started construction of a new refining facility, called IC3, at its Ferrometals (Pty.) Ltd. plant, at Witbank. IC3 was scheduled for completion in 1986. Upon completion, IC3 was to produce medium- and low-carbon ferrochromium (2% to 6% carbon) from high-carbon ferrochromium (6% to 8%). The high-carbon ferrochromium was to be fed as hot metal. IC3 was to have a refining capacity of about 50,000 tons per year. Samancor planned construction of a ferrochromium plant at its Ruighoek Mine. Plant construction was to start in 1986. Samancor erected a beneficiation plant at its Mooinooi Mine at a cost of about $75,000. The plant was designed to produce chemical- and metallurgical-grade concentrates from a stockpile of fines. Until 1985, Mooinooi produced only lump ore for sale, resulting in a 340,000-ton stockpile of fines. Samancor was to install a new ferrochromium production process at its Ferrometals Ltd. plant at Witbank. The new process involves kiln reduction of chromite with coal, followed by submerged-arc furnace reduction to complete the smelting process. Construction was to start in 1986, and the new process was to be operational in 1987 at an annual production capacity of about 60,000 tons per year. This process was to replace about 45,000 tons per year of conventional submerged-arc production capacity.

Middleburg Steel & Alloys Holdings (Pty.) Ltd. (MSA) continued development of its direct current transferred-arc plasma furnace at its Krugersdorp plant. MSA was also studying the feasibility of using a kiln roasting prereduction process.

### Table 16.—Chromite: World production, by country[1]

(Thousand short tons, gross weight)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Albania[e] | [r]783 | [r]744 | [r]755 | [r]794 | 909 |
| Brazil[3] | 261 | 304 | 171 | 282 | 303 |
| Cuba[4] | 23 | 30 | 37 | 41 | 44 |
| Cyprus | 11 | 3 | -- | -- | -- |
| Finland[4] | 454 | 380 | 271 | 492 | 500 |
| Greece[5] | [r]27 | [r]32 | 30 | 68 | 68 |
| India | 369 | 374 | 465 | 466 | [6]610 |
| Iran[e] | 35 | 45 | 55 | 55 | 55 |
| Japan | 12 | 12 | 9 | 8 | [6]13 |
| Madagascar | 110 | 49 | 50 | 66 | 66 |
| New Caledonia | 5 | 55 | 101 | 93 | [6]87 |
| Pakistan | 2 | [r]4 | 7 | 3 | 4 |
| Philippines | 484 | 355 | 294 | 286 | [6]284 |
| South Africa, Republic of[4 7] | 3,164 | 2,385 | 2,460 | 3,314 | [6]3,682 |
| Sudan | [e]28 | [e]21 | [e]22 | [r e]22 | 22 |
| Turkey | [r]442 | [r]499 | 381 | 537 | 496 |
| U.S.S.R.[e 8] | 3,200 | 3,240 | 3,240 | [r]3,240 | 3,240 |
| Vietnam[e] | 17 | 18 | 18 | 20 | 17 |
| Yugoslavia | ([9]) | -- | -- | -- | -- |
| Zimbabwe | 591 | 476 | 463 | 525 | 551 |
| **Total** | **[r]10,018** | **[r]9,026** | **8,829** | **10,312** | **10,961** |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Table includes data available through July 1, 1986.

[2]In addition to the countries listed, Bulgaria, China, and North Korea may also produce chromite, but output is not reported quantitatively and available general information is inadequate for formulation of reliable estimates of output levels. Figures for all countries represent marketable output unless otherwise noted.

[3]Figures are sum of (1) crude ore sold directly for use and (2) concentrate output, both as reported in Brazilian sources. Total run-of-mine crude ore production (not comparable to data for other countries) was as follows, in thousand short tons: 1981—1,021; 1982—736; 1983—517; 1984—782; and 1985—800 (estimated).

[4]Production of marketable product (direct-shipping lump ore plus concentrates and foundry sand).

[5]Exports of direct-shipping ore plus production of concentrates.

[6]Reported figure.

[7]Excludes production by Bophuthatswana, which was as follows, in thousand short tons: 1982—295 and 1983—302.

[8]Estimates for 1981 and 1985 are based in part on crude output reported in Soviet sources as follows, in thousand short tons: 1981—3,600 and 1985—3,700.

[9]Less than 1/2 unit.

**Sweden.**—Construction of SwedeChrome AB's high-carbon ferrochromium plant started in Malmö. SwedeChrome was to use SKF Steel Engineering AB's plasma process technology. The plant was to have a total annual ferrochromium production capacity of 85,000 to 90,000 tons per year divided equally between two furnaces. The plant was also to supply excess thermal energy to Malmö's local district heating system. SKF's plasma process was to use plasma heaters in a shaft furnace. Advantages of this plasma process include higher chromium recovery, increased capability of excess process energy recovery, use of less costly fine-sized raw materials (agglomeration not required), and lack of constraints on furnace burden composition because of electrical resistivity requirements. Site preparation was completed and plant construction begun. Equipment installation and production startup was planned for 1986.

**Turkey.**—Etibank continued development of a chromite ore concentrator and ferrochromium production plant. With completion targeted for 1987, the concentrator was to have a production capacity of about 250,000 tons per year of concentrate and the ferrochromium plant was to increase capacity from 50,000 to 150,000 tons per year of high-carbon ferrochromium. The concentrator was at Kefdag, and the ferrochromium plant at Elazig.

Bomar Resources Inc., United States, entered a joint venture with Etibank and Egemetal Madencilik AS to study chromite resources in the Orhaneli region near Bursa in northwest Turkey.

Bilfer Madencilik AS reactivated 13 chromite mines in 6 Provinces because of improved market conditions.

**United Kingdom.**—The United Kingdom announced its decision to dispose of its strategic stockpile. March 1986 was the date by which 25% of the stockpile was to have been sold.

## WORLD RESERVES

Geological aspects of the Bushveld Complex, the Republic of South Africa, the largest resource of chromium, were reviewed. The geologic implications derived from studies of chromite resources in the Potgietersrus, Nietverdiend, and Zwartkop Mine areas were discussed. Geologic aspects of the UG-2 chromitite layer were also discussed.[9]

The Manitoba Department of Energy and Mines, Canada, reevaluated the Bird River sill chromite resources. The Page, Chrome, Bird Lake, and Euclid properties were calculated to have a geologic reserve (measured plus indicated) of about 2.7 million tons of contained $Cr_2O_3$.[10]

Australia, previously a chromite producer, evaluated its chromite resources. Over 50 deposits were analyzed. Demonstrated paramarginal resources were set at about 2.3 million tons and inferred subeconomic resources at about 20 million tons.[11]

## TECHNOLOGY

The Bureau of Mines conducted resource identification and beneficiation studies as part of its domestic mineral assessment program. Chromite deposits along the Border Ranges Fault, southern Alaska, were investigated and described, and the minerals were characterized and beneficiated.[12] The 94 subeconomic deposits were found to range in size from less than 1,000 to greater than 1,000,000 tons of contained chromic oxide. Samples from the deposits were peridotites and chromites that consisted primarily of chromite, olivine, and serpentine. Beneficiation by grinding, sizing, and gravity concentration yielded chromium recoveries ranging from 37% to 95%. The Bureau studied the bulk mineralogy and geochemistry of Alaskan chromite spinels.[13] Systematic differences in chemical content were found between samples from the Chugach mountain range and the Alaskan interior. Considerable mineralogical variability was found between and within these groups. Alaskan chromium deposits studied by the Bureau from 1979 to 1984 were found to contain 3 to 4 million tons of chromic oxide in 132 podiform deposits and 1 placer deposit.[14]

The Bureau researched chromite mineral extraction to increase extraction efficiency and economy, and devised a process to recover chromium as chemicals from domestic chromites that contain silicon and aluminum impurity levels that are too high to permit processing by present industrial processes.[15] The Bureau process consists of reacting chromite with molten sodium hydroxide under oxidizing conditions to form sodium chromate. Domestic chromites from Alaska, California, and Oregon were successfully treated by this procedure. The Bureau devised a column flotation technique and compared it with conventional flotation of Montana chromite.[16] Column flotation produced higher concentrate grades and recoveries than conventional chromite flotation for both deslimed and undeslimed chromite ore. The Bureau upgraded high-iron domestic chromite concentrates by a carbonyl process.[17] The high-iron chromites were reduced to convert iron oxides to the metal, then were treated with carbon monoxide to convert part of the iron to iron pentacarbonyl. The iron pentacarbonyl was then extracted from the concentrate. Chromic oxide content was improved by as much as 10% and chromium-to-iron ratio increased by up to threefold compared with that of the starting concentrates. The Bureau researched environmental issues associated with chromite extraction from the Stillwater Complex, MT.[18] Specific land, water, air, and other environmental factors were identified and analyzed as to how they would relate to mining of chromite deposits. Shrinkage stoping mining methods and gravity concentration milling were assumed as part of the environmental issues study. With the exception of technology for ferrochromium smelter sludge reclamation, all technology necessary for development was found to be available and sound.

The Bureau researched the potential for reducing the chromium content of stainless and alloy steels to improve chromium use technology. Chromium-nickel stainless steels with molybdenum, copper, and vanadium for corrosion-resistant applications, and with silicon and aluminum for heat-resistant applications, were studied.[19] For several reduced chromium stainless steels, tensile properties were evaluated, corrosion rates were measured, welding performance was evaluated, stress rupture properties were measured, and oxidation tests were performed. Additions such as molybdenum, silicon, and aluminum were found to be potential substitutes for about one-half the chromium in stainless steels for many applications. The Bureau performed oxidation studies, obtained mechanical properties, determined stress rupture strength data, and investigated melting, casting, and working characteristics for iron-manganese-aluminum alloys as a potential substitute for stainless steels.[20] The alloys studied did not exhibit good oxidation resistance during mild thermal cycling and were problematic to melt, cast, and cut. The alloys were easily hot worked and had good mechanical properties unless aged. Iron-chromium-nickel-aluminum alloys were studied as potential substitutes for stainless steels used in sulfur-containing environments.[21] With minor additions of titanium, manganese, and silicon to improve workability, sulfidation resistance was found to exceed that of stainless steel types 304 and 316; oxidation resistance was equivalent to that of type 310; and mechanical properties approached those of type 310. The Bureau investigated a cast-on hard-surfacing technique that improves wear resistance.[22] The cast-on surface was found to be a potential substitute for weld-rod hard facing.

The Bureau studied in-plant recycling of speciality steelmaking particulate wastes.[23] Particulate waste such as flue dust, mill scale, and grinding swarf was pelletized and reduced in an electric-arc furnace. Consistent recoveries of about 90% of the chromium were achieved. The Bureau cosponsored a workshop on conservation and substitution technology for chromium in bearings.[24] Strategies such as substitution of alternate materials, including metals and nonmetals, and use of extended life bearings, were identified.

The U.S. Department of Defense developed a microprocessor-controlled chromium plating process and studied the effect of plating conditions on the structure of electrodeposited chromium.[25]

The National Materials Advisory Board studied the potential industrial application of plasma processing technology.[26] The report identified plasma technology as potentially applicable to ferrochromium production and to the recovery of chromium from dusts. Current industrial applications of plasma technology to ferrochromium production, low-grade chromium ore processing, and chromium recovery from steel mill baghouse dust were identified.

The National Institute for Metallurgy, Republic of South Africa, developed an accurate and precise method for the determination of iron and chromium in chromite.[27]

The economic recovery of chromite from the UG-2 seam of the Bushveld Complex was studied by the Council for Mineral Technology (Mintek), Republic of South Africa.[28] A beneficiation process to produce chromite concentrate was developed and tested at pilot plant and production scales. A low-grade chromite concentrate was found to have been economically recoverable from UG-2 seam material currently mined by Western Platinum Ltd. for its platinum content.

Mintek also studied chromite reduction and energy transfer in a submerged-arc furnace. Chromite combined with graphite and reduced in an argon atmosphere at 1,300° C was found to react sequentially. First ferric iron in chromite ore was reduced to the ferrous state, followed by reduction of ferrous to metallic iron. Chromium was then reduced.[29] Heat flows were measured in the submerged-arc furnace and a time-dependent, two-dimensional mathematical model developed.[30]

Ferrochromium production is energy intensive, and new smelting techniques are being developed by industry to lower energy costs. Traditional smelting methods use electric submerged-arc furnaces. As alternatives to the traditional smelting practice, kiln roast prereduction and plasma furnace smelting are being studied. The Ministry of International Trade and Industry, Japan, began construction of a pilot plant at Nippon Steel Corp.'s Kimitsu Works to study ferrochromium production with stainless steel production.[31] Samancor was to restructure its Ferrometals plant to produce ferrochromium from chromite prereduced with coal in a kiln roasting process. Mintek, Republic of South Africa, studied the reduction of chromite in a transferred-arc plasma furnace.[32] The transferred-arc plasma technology was found to be a potential alternative to traditional submerged-arc technology. The plasma technology was found capable of processing low-grade fine chromite ore that is precluded from direct electric submerged-arc processing. The plasma furnace was also studied for the purpose of recycling ferrochromium metal fines.[33] Mintek found that these fines could be remelted and consolidated in a plasma furnace with metal recoveries of over 90%.

Finland reported the production of ferrochromium from low-grade ores.[34] The process of producing charge-grade ferrochromium by smelting pelletized and hardened concentrates from chromium ore in an enclosed electric furnace was described.

Commercial chromium-recovery membranes are being developed. A coupled-transport liquid-membrane chromium extraction process that was demonstrated effective on plating solution waste was to have been applied to a commercial process.

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# Clays

## By Sarkis G. Ampian[1]

Total quantity of clays sold or used by domestic producers increased 3% in tonnage but decreased slightly in value. Clays in one or more of six classification categories, ball clay, bentonite, common clay and shale, fire clay, fuller's earth, or kaolin, were produced in 44 States and Puerto Rico during 1985. Clay production, as in 1984, was not reported in Alaska, Delaware, the District of Columbia, Hawaii, Rhode Island, Vermont, or Wisconsin. The leading seven States, in descending order, were Georgia, Texas, North Carolina, Wyoming, California, Ohio, and Alabama. Unpredictable shortages of natural gas and the cost of fuels were major concerns to clay producers and manufacturers until yearend, when an oil glut caused by world overproduction started softening energy prices. Industrywide efforts to economize by reducing capital and/or energy costs, although persistent during the year, intensified at yearend. Environmental restrictions and associated costs, combined with persistent high capital costs, continued to hinder production.

Production of common clay and shale increased because of an upturn in construction, due in part to the softening of interest rates and improving business climate, that increased demand for clay building materials—brick, portland cement, floor and wall tile, and vitrified sewer pipe. An exception to the Nation's buoyant construction rates were those noted in the oil producing States of Louisiana, Oklahoma, and Texas, because declining oil revenues depressed residential, business, and governmental construction activity. Increases in production of the specialty clays, ball clay and fuller's earth, were caused largely by an improvement in the overall economy. Production of bentonite, fire clay, and kaolin declined because their major consumers, the steel, oil and gas exploration, and foundry industries, were in a period of readjustment with lower production levels.

Kaolin accounted for 17% of the clay production but 59% of clay value. Kaolin production of 7.8 million short tons decreased from that of 1984.

**Domestic Data Coverage.**—Domestic production data for clays are developed by the Bureau of Mines from one voluntary survey of U.S. operations. Of the 1,084 operations covered by the survey, 1,004 responded, representing 93% of the total clay and shale production sold or used shown in table 1.

Table 1.—Salient U.S. clays and clay products statistics[1]

(Thousand short tons and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Domestic clays sold or used by producers: | | | | | |
| Quantity | 44,379 | 35,345 | 40,858 | r43,702 | 44,974 |
| Value | $988,845 | $825,064 | $931,092 | r$1,082,127 | $1,011,377 |
| Exports: | | | | | |
| Quantity | 3,151 | 2,619 | 2,484 | 2,699 | 2,780 |
| Value | $292,914 | $267,700 | $254,237 | $295,733 | $309,871 |
| Imports for consumption: | | | | | |
| Quantity | 33 | 24 | 21 | 32 | 41 |
| Value | $7,895 | $4,514 | $3,488 | $4,868 | $5,981 |
| Clay refractories shipments: Value | $609,949 | $559,655 | $595,299 | $782,308 | $629,738 |
| Clay construction products shipments: Value | $971,824 | $923,459 | $1,160,543 | $1,342,196 | $1,427,851 |

rRevised.

[1] Excludes Puerto Rico.

### Table 2.—Clays sold or used by producers in the United States in 1985, by State[1]

(Short tons unless otherwise specified)

| State | Ball clay | Bentonite | Common clay and shale | Fire clay | Fuller's earth | Kaolin | Total | Total value |
|---|---|---|---|---|---|---|---|---|
| Alabama | -- | W | 1,630,739 | 130,000 | -- | 111,886 | [2]1,872,625 | [2]$13,139,143 |
| Arizona | -- | 32,824 | 153,608 | -- | -- | -- | 186,432 | 1,503,279 |
| Arkansas | -- | -- | 911,335 | -- | -- | 140,271 | 1,051,606 | 10,769,180 |
| California | -- | 112,890 | 2,062,256 | W | -- | 28,138 | [3]2,203,284 | [3]26,600,429 |
| Colorado | -- | 80 | 282,411 | 20,384 | -- | -- | 302,875 | 1,742,690 |
| Connecticut | -- | -- | 106,033 | -- | -- | -- | 106,033 | 631,873 |
| Florida | -- | -- | 248,680 | -- | 387,076 | 36,323 | 672,079 | 33,074,154 |
| Georgia | -- | -- | 1,732,742 | -- | 593,033 | 6,345,205 | 8,670,980 | 575,096,905 |
| Idaho | -- | W | -- | W | -- | 1,505 | [2] [3]1,505 | W |
| Illinois | -- | -- | 265,467 | -- | W | -- | [4]265,467 | [4]876,123 |
| Indiana | -- | -- | 739,711 | -- | -- | -- | 739,711 | 2,776,446 |
| Iowa | -- | -- | 503,298 | -- | -- | -- | 503,298 | 2,449,931 |
| Kansas | -- | 24,000 | 854,177 | -- | -- | -- | 878,177 | 5,325,709 |
| Kentucky | W | -- | 661,176 | W | -- | -- | 774,780 | 6,486,980 |
| Louisiana | -- | -- | 333,619 | -- | -- | -- | 333,619 | 7,016,609 |
| Maine | -- | -- | 49,500 | -- | -- | -- | 49,500 | 99,555 |
| Maryland | W | -- | 336,085 | -- | -- | -- | [5]336,085 | [5]1,646,991 |
| Massachusetts | -- | -- | 264,538 | -- | -- | -- | 264,538 | 1,388,090 |
| Michigan | -- | -- | 1,477,309 | -- | -- | -- | 1,477,309 | 5,513,822 |
| Minnesota | -- | -- | W | -- | -- | W | W | W |
| Mississippi | W | 197,531 | 850,706 | -- | W | -- | 1,558,300 | 34,864,168 |
| Missouri | -- | -- | 1,204,854 | 283,697 | W | 56,701 | [4]1,545,252 | [4]10,271,129 |
| Montana | -- | 254,398 | 24,190 | 503 | -- | -- | 279,091 | 8,295,649 |
| Nebraska | -- | -- | 244,228 | -- | -- | -- | 244,228 | 718,214 |
| Nevada | -- | 79,861 | -- | -- | W | W | [4] [6]79,861 | [4] [6]3,775,947 |
| New Hampshire | -- | -- | W | -- | -- | -- | W | W |
| New Jersey | -- | -- | 120,000 | 10,166 | -- | -- | 130,166 | 2,050,079 |
| New Mexico | -- | -- | 57,048 | 2,767 | -- | -- | 59,815 | 160,714 |
| New York | -- | -- | 699,764 | -- | -- | -- | 699,764 | 3,129,207 |
| North Carolina | -- | -- | 2,611,455 | -- | -- | 76,864 | 2,688,319 | 10,476,986 |
| North Dakota | -- | -- | W | -- | -- | -- | W | W |
| Ohio | -- | -- | 1,873,037 | 241,045 | -- | -- | 2,114,082 | 10,580,605 |
| Oklahoma | -- | -- | 996,522 | -- | -- | -- | 996,522 | 2,337,657 |
| Oregon | -- | -- | 188,026 | -- | -- | -- | 188,026 | 284,626 |
| Pennsylvania | -- | -- | 1,061,607 | 80,610 | -- | W | [6]1,142,217 | [6]5,292,781 |
| Puerto Rico | -- | -- | 118,192 | -- | -- | -- | 118,192 | 263,568 |
| South Carolina | -- | -- | 1,029,178 | -- | W | 866,812 | [4]1,895,990 | [4]37,695,224 |
| South Dakota | -- | W | 117,065 | -- | -- | -- | [2]117,065 | [2]309,052 |
| Tennessee | 664,555 | -- | 579,069 | -- | W | -- | [4]1,243,624 | [4]25,912,698 |
| Texas | 30,201 | 46,762 | 3,919,159 | 21,196 | W | W | 4,106,646 | 28,059,057 |
| Utah | -- | 14,006 | 317,725 | 500 | -- | -- | 332,231 | 2,509,304 |
| Virginia | -- | -- | 786,295 | -- | 28,000 | -- | 814,295 | 6,976,908 |
| Washington | -- | -- | 242,914 | -- | -- | -- | 242,914 | 1,402,107 |
| West Virginia | -- | -- | 233,269 | 98,064 | -- | -- | 331,333 | 3,342,451 |
| Wyoming | -- | 2,116,085 | 185,917 | -- | -- | -- | 2,302,002 | 64,146,205 |
| Undistributed | 206,923 | 316,843 | 95,421 | 85,482 | 1,051,172 | 129,617 | [7]1,172,463 | [7]52,647,917 |
| **Total** | **901,679** | **3,195,280** | **30,168,325** | **974,414** | **2,059,281** | **7,793,822** | **45,092,801** | **1,011,640,162** |

W Withheld to avoid disclosing company proprietary data; included with "Total" and/or "Undistributed."

[1] Includes Puerto Rico.

[2] Excludes bentonite.

[3] Excludes fire clay.

[4] Excludes fuller's earth.

[5] Excludes ball clay.

[6] Excludes kaolin.

[7] Incomplete total; difference included with individual State totals.

**Table 3.—Number of mines[1] from which producers sold or used clays in the United States in 1985, by State**

| State | Ball clay | Bentonite | Common clay and shale | Fire clay | Fuller's earth | Kaolin | Total |
|---|---|---|---|---|---|---|---|
| Alabama | -- | 1 | 26 | 5 | -- | 8 | 40 |
| Arizona | -- | 5 | 6 | -- | -- | -- | 11 |
| Arkansas | -- | -- | 18 | -- | -- | 5 | 23 |
| California | -- | 5 | 53 | 1 | -- | 5 | 64 |
| Colorado | -- | 1 | 28 | 8 | -- | -- | 37 |
| Connecticut | -- | -- | 2 | -- | -- | -- | 2 |
| Florida | -- | -- | 3 | -- | 4 | 1 | 8 |
| Georgia | -- | -- | 18 | -- | 8 | 85 | 111 |
| Idaho | -- | 1 | 1 | -- | -- | 1 | 3 |
| Illinois | -- | -- | 9 | -- | 2 | -- | 11 |
| Indiana | -- | -- | 17 | -- | -- | -- | 17 |
| Iowa | -- | -- | 11 | -- | -- | -- | 11 |
| Kansas | -- | 1 | 20 | -- | -- | -- | 21 |
| Kentucky | 6 | -- | 11 | 2 | -- | -- | 19 |
| Louisiana | -- | 1 | 8 | -- | -- | -- | 9 |
| Maine | -- | -- | 4 | -- | -- | -- | 4 |
| Maryland | 1 | -- | 7 | -- | -- | -- | 8 |
| Massachusetts | -- | -- | 3 | -- | -- | -- | 3 |
| Michigan | -- | -- | 8 | -- | -- | -- | 8 |
| Minnesota | -- | -- | 1 | -- | -- | 1 | 2 |
| Mississippi | 1 | 4 | 21 | -- | 2 | -- | 28 |
| Missouri | -- | -- | 14 | 35 | 2 | 6 | 57 |
| Montana | -- | 12 | 5 | 1 | -- | -- | 18 |
| Nebraska | -- | -- | 5 | -- | -- | -- | 5 |
| Nevada | -- | 6 | -- | -- | -- | 2 | 8 |
| New Hampshire | -- | -- | 1 | -- | -- | -- | 1 |
| New Jersey | -- | -- | 2 | 1 | -- | -- | 3 |
| New Mexico | -- | -- | 4 | 2 | -- | -- | 6 |
| New York | -- | -- | 11 | -- | -- | -- | 11 |
| North Carolina | -- | -- | 50 | -- | -- | 2 | 52 |
| North Dakota | -- | -- | 4 | -- | -- | -- | 4 |
| Ohio | -- | -- | 53 | 16 | -- | -- | 69 |
| Oklahoma | -- | -- | 19 | -- | -- | -- | 19 |
| Oregon | -- | -- | 6 | -- | -- | -- | 6 |
| Pennsylvania | -- | -- | 37 | 19 | -- | 2 | 58 |
| South Carolina | -- | -- | 26 | -- | 1 | 22 | 49 |
| South Dakota | -- | 1 | 1 | -- | -- | -- | 2 |
| Tennessee | 23 | -- | 9 | -- | 1 | -- | 33 |
| Texas | 1 | 8 | 69 | 2 | 2 | 1 | 83 |
| Utah | -- | 4 | 14 | 1 | 1 | -- | 20 |
| Virginia | -- | -- | 15 | -- | 1 | -- | 16 |
| Washington | -- | -- | 9 | 2 | -- | -- | 11 |
| West Virginia | -- | -- | 3 | 1 | -- | -- | 4 |
| Wyoming | -- | 107 | 2 | -- | -- | -- | 109 |
| Total | 32 | 157 | 634 | 96 | 24 | 141 | 1,084 |

[1] Includes both active and idle operations.

## DOMESTIC PRODUCTION, PRICES, AND FOREIGN TRADE, BY TYPE OF CLAY

### KAOLIN

Domestic production of kaolin decreased slightly to 7.8 million tons. The average unit value of all grades of kaolin decreased 4% to $76.43 per ton. Kaolin was again produced in 18 States. Two States, Georgia and South Carolina, accounted for 93% of total production. Arkansas ranked third, and Alabama, fourth. Both Alabama and Arkansas produce refractory- and alum-grade kaolins. Kaolin producers reported major domestic end uses for their clay as follows: paper coating, 35%; paper filling, 18%; refractories, 8%; face brick, 7%; fiberglass and insulation, and rubber, 5% each; and catalysts and chemicals, 3% each.

Kaolin is defined as a white, claylike material approximating the mineral kaolinite. It has a specific gravity of 2.6 and a fusion point of 1,785° C. The other kaolin-group minerals, such as halloysite and dickite, are encompassed.

Overcapacity of water-washed and calcined kaolin grades continued to worry the major producers who are heavily tied to the presently depressed paper industry. Competition for Asian and European markets, traditionally supplied by domestic water-washed kaolin producers, intensified because of the strong U.S. dollar and foreign overcapacity. Finished paper-stock imports further compounded the problem. Kaolin sales for refractories appeared to have leveled off. The refractory industry adjusted to new lower levels of production brought about by changes in technology and imports. Production of the three paper-grade kaolins was mixed compared with that of 1984. Low-temperature calcined kaolin production increased 3%, while that of water-washed and delaminated decreased 5% and 4%, respectively.

Several major acquisitions started at yearend 1984 were finalized during the year. The Engelhard Corp. Specialty Chemicals Div. purchased Freeport Kaolin Co. from Freeport-McMoRan Inc. for $100 million. Rationalization of the present Engelhard and Freeport operations was proceeding. A letter of intent for The Morie Co. Inc., Energy and Minerals Inc., to buy Ottawa Silica Co. was terminated by the parent company, South Jersey Industries Inc., at yearend. Ottawa Silica produces filler-grade kaolin from sand kaolin deposits near Kosse, TX. Other diversified mineral-based companies were reportedly interested in acquiring Ottawa Silica. In another company move, Standard Oil Co. (Indiana) sold the shares of its minerals subsidiary, Cyprus Minerals Co., to its shareholders. The new operating company, Cyprus Minerals, includes Cyprus Industrial Minerals with kaolin and ball clay operations in Georgia, South Carolina, and Tennessee.

All Georgia and South Carolina kaolin filler-extender-pigment producers, water-washed and air-floated, continued to modernize, instead of expanding, to reduce operating costs. Emphasis continued to be placed on energy related costs. In this regard, the first superconducting magnet for use in removing iron-bearing impurities from wet kaolin processing streams was installed by the J. M. Huber Corp. in its Wrens, GA, complex. The new magnetic separator reportedly requires 80% less electric power than the currently used varieties. Georgia Kaolin Co. was planning to convert the spray-dryers in its American Industrial Clay Co. plant in Deepstep, GA, from natural gas to wood gas produced from a wood gasification facility. The facility included provisions for a cogenerating internal combustion engine, which was to provide exhaust heat to dry the wood chips prior to gasification. J. M. Huber, at its Langley, SC, air-float kaolin plant, began fueling its dryers with methane gas, instead of natural gas, drawn from decomposed waste in a local landfill. Preliminary estimates indicated savings of approximately $70,000 yearly from the conversion. Evans Clay Co., McIntyre, GA, planned to install additional bulk kaolin storage capacity and silo-to-railcar loading equipment. The emissions were to be controlled by specially installed baghouse collectors at each transfer point. Engelhard started operating its newly expanded proprietary oil-refining catalyst plant at its Attapulgus, GA, site, which also produces attapulgite-type fuller's earth products. The catalyst is prepared from kaolin-type clays.

C-E Minerals, a division of Combustion-Engineering Inc., completed a large expansion at its Andersonville, GA, complex. The complex is capable of supplying 600,000 tons per year of various alumina-silica kaolin calcines for refractory and foundry use. The expansion featured a virtual 100% conversion to coal firing from natural gas, and a new integrated instrumental quality control procedure designed to automatically monitor material along the entire flowsheet from mining to finished products. The coal was furnished from C-E's own metallurgical-grade coal mines in West Virginia.

Properties in Minnesota and Vermont were proposed for kaolin mining and processing ventures. Northwestern Portland Cement Co. and Vermont Minerals and Pigments Co. announced plans for operating in the Mocassin Springs development east of Redwood Falls, MN, and on Bald Mountain, in northwest Bennington, VT, respectively.

**Table 4.—Kaolin sold or used by producers in the United States, by State**

| State | 1984 | | 1985 | |
|---|---|---|---|---|
| | Short tons | Value | Short tons | Value |
| Alabama | 238,520 | $18,631,800 | 111,886 | $1,959,747 |
| Arkansas | 85,898 | 5,681,092 | 140,271 | 8,877,441 |
| California | 59,705 | 1,838,393 | 28,138 | 760,752 |
| Florida | 33,004 | 2,438,372 | 36,323 | 2,843,000 |
| Georgia | 6,508,319 | 562,696,774 | 6,345,205 | 534,980,001 |
| Idaho | 1,464 | W | 1,505 | W |
| Missouri | 68,137 | 1,946,674 | 56,701 | 1,701,030 |
| North Carolina | 46,787 | 1,075,548 | 76,864 | 1,943,619 |
| South Carolina | 776,567 | 33,404,087 | 866,812 | 35,309,338 |
| Other[1] | 134,268 | 6,674,390 | 129,617 | 7,240,830 |
| Total | 7,952,669 | 634,387,130 | 7,793,822 | 595,615,758 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes Minnesota, Nevada, Pennsylvania, Texas, and data indicated by symbol W.

Exports of kaolin, as reported by the U.S. Department of Commerce, decreased only 3% to 1.88 million tons valued at $174 million, despite a strong U.S. dollar and foreign competition. Kaolin, including calcined material, was exported to 70 countries, 2 more than in 1984. The major recipients were Japan, 32%; Canada, 20%; the Netherlands, 11%; Italy, 8%; and Mexico, 7%. Kaolin producers reported end uses for their exports as follows: paper coating, 61%; refractories, 12%; paper filling, 11%; paint, 9%; rubber, 3%; and other, including ceramics and plastics, the remainder.

Kaolin imports decreased 12% to 9,387 tons valued at $996,000. The unit price of kaolin imported from the United Kingdom, the largest importing country, increased nearly 33% to $102.93 per ton.

Kaolin prices quoted in the trade journals remained unchanged. Chemical Marketing Reporter, December 31, 1985, quoted prices as follows:

| | |
|---|---|
| Water-washed, fully calcined, bags, carload lots, f.o.b. Georgia, per ton | $255.00 |
| Paper-grade, uncalcined, bulk, carload lots, f.o.b. Georgia, per ton: | |
| No. 1 coating | 94.00 |
| No. 2 coating | 75.00 |
| No. 3 coating | 73.00 |
| No. 4 coating | 70.00 |
| Filler, general purpose, same basis per ton | 58.00 |
| Delaminated, water-washed, uncalcined, paint-grade, 1-micrometer average, same basis, per ton | 132.00 |
| Dry-ground, air-floated, soft, same basis, per ton | 60.00 |
| National Formulary, powder, colloidal, bacteria controlled, 50-pound bags, 5,000-pound lots, per pound | .24 |

### Table 5.—Kaolin sold or used by producers in the United States, by kind

| Kind | 1984 | | 1985 | |
|---|---|---|---|---|
| | Short tons | Value | Short tons | Value |
| Air-float | 1,153,291 | $62,401,704 | 1,275,733 | $66,186,128 |
| Calcined[1] | 1,204,117 | 157,909,408 | 1,108,098 | 116,319,429 |
| Delaminated | 764,566 | 72,529,476 | 735,508 | 72,075,882 |
| Unprocessed | 891,645 | 16,734,107 | 914,263 | 14,419,612 |
| Water-washed | 3,939,050 | 324,812,440 | 3,759,725 | 326,664,707 |
| Total | 7,952,669 | 634,387,130 | 7,793,822 | 595,615,758 |

[1] Includes both low-temperature filler and high-temperature refractory grades.

### Table 6.—Calcined kaolin sold or used by producers in the United States, by State

| State | High-temperature | | Low-temperature | |
|---|---|---|---|---|
| | Short tons | Value | Short tons | Value |
| 1984 | | | | |
| Georgia and Alabama | 578,520 | $40,976,800 | [1]510,372 | [1]$107,065,496 |
| Other | [2]58,255 | [2]5,020,187 | [3]56,970 | [3]4,846,920 |
| Total | 636,775 | 45,996,987 | 567,342 | 111,912,416 |
| 1985 | | | | |
| Georgia and Alabama | 432,495 | 10,565,958 | [1]532,275 | [1]91,979,229 |
| Other | [2]90,587 | [2]8,691,212 | [3]52,791 | [3]5,083,030 |
| Total | 523,082 | 19,257,170 | 585,066 | 97,062,259 |

[1] Excludes Alabama.
[2] Includes Arkansas, California (1984), and Idaho.
[3] Includes Pennsylvania, South Carolina, and Texas.

### Table 7.—Georgia kaolin sold or used by producers, by kind

| Kind | 1984 | | 1985 | |
|---|---|---|---|---|
| | Short tons | Value | Short tons | Value |
| Air-float | 591,869 | $27,989,083 | 739,563 | $31,824,875 |
| Calcined[1] | 850,372 | 129,410,496 | 945,106 | 100,875,939 |
| Delaminated | 764,566 | 72,529,476 | 735,508 | 72,075,882 |
| Unprocessed | 395,094 | 9,799,483 | 196,312 | 5,594,126 |
| Water-washed | 3,906,418 | 322,968,236 | 3,728,721 | 324,609,679 |
| Total | 6,508,319 | 562,696,774 | 6,345,205 | 534,980,001 |

[1] Includes both low-temperature filler and high-temperature refractory grades.

## Table 8.—Georgia kaolin sold or used by producers, by use

(Short tons)

| Use | 1984 |  |  |  | 1985 |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  | Air-float | Unprocessed[1] | Water-washed[2] | Total | Air-float | Unprocessed[1] | Water-washed[2] | Total |
| Domestic: |  |  |  |  |  |  |  |  |
| Adhesives | 9,556 | -- | 63,276 | 72,832 | 7,413 | -- | 73,399 | 80,812 |
| Aluminum sulfate and other chemicals | -- | 250,000 | 8,819 | 258,819 | 243 | 109,923 | 351 | 110,517 |
| Animal feed | 17 | -- | 142 | 159 | 88 | -- | 1,264 | 1,352 |
| Asphalt tile and linoleum | 3,635 | -- | -- | 3,635 | 3,776 | -- | -- | 3,776 |
| Catalysts (oil-refining) | 54,839 | -- | 115,854 | 170,693 | 60,767 | 253 | 106,717 | 167,737 |
| Cement, portland | -- | 72,700 | -- | 72,700 | -- | -- | -- | -- |
| Electrical porcelain | 16,393 | -- | -- | 16,393 | 13,086 | -- | -- | 13,086 |
| Face brick | -- | 20,700 | -- | 20,700 | -- | 25,943 | 55,285 | 81,228 |
| Fiberglass and mineral wool | 117,520 | -- | 51,123 | 168,643 | 109,130 | -- | 61,373 | 170,503 |
| Fine china and dinnerware; crockery and earthenware | 37,813 | 1,399 | -- | 39,212 | 15,518 | 1,453 | -- | 16,971 |
| Firebrick, blocks and shapes | 2,567 | 4,643 | -- | 7,210 | 2,901 | 940 | -- | 3,841 |
| Floor and wall tile, ceramic | 20,866 | -- | -- | 20,866 | 8,412 | -- | -- | 8,412 |
| Flue linings; high-alumina brick and specialties; glazes, glass, enamels | 20,000 | 3,030 | -- | 23,030 | -- | 3,064 | -- | 3,064 |
| Foundry sand | -- | -- | 41 | 41 | -- | -- | 364 | 364 |
| Grogs and calcines, refractory | -- | 245,000 | -- | 245,000 | 1,544 | 260,567 | -- | 262,111 |
| Ink | W | -- | W | W | W | -- | W | W |
| Kiln furniture, refractory and mortar cement | W | W | -- | W | W | W | -- | W |
| Medical, pharmaceutical, cosmetic | -- | -- | 1,894 | 1,894 | 1,233 | -- | 1,202 | 2,435 |
| Paint | 14,314 | -- | 187,473 | 201,787 | 21,734 | -- | 150,825 | 172,559 |
| Paper coating | 8,827 | -- | 2,465,748 | 2,474,575 | -- | -- | 2,263,846 | 2,263,846 |
| Paper filling | 89,484 | -- | 890,799 | 980,283 | 27,107 | -- | 1,144,228 | 1,171,335 |
| Plastics | 2,400 | -- | 44,160 | 46,560 | 5,648 | -- | 35,414 | 41,062 |
| Pottery | 271 | 699 | -- | 970 | 9,224 | 726 | -- | 9,950 |
| Roofing granules | 17,944 | -- | -- | 17,944 | 21,878 | -- | -- | 21,878 |
| Rubber | 24,803 | -- | 60,487 | 85,290 | 92,709 | 1,213 | 28,962 | 122,884 |
| Sanitary ware | 108,579 | 11,891 | 51 | 120,521 | 122,630 | 12,353 | 728 | 135,711 |
| Miscellaneous, air-float: |  |  |  |  |  |  |  |  |
| Common brick, fertilizers, gypsum products, pesticides and related products, roofing and structural tile, other uses not specified | 11,190 | -- | -- | 11,190 | 66,083 | -- | -- | 66,083 |
| Miscellaneous, unprocessed: |  |  |  |  |  |  |  |  |
| Fertilizers, pesticides and related products, other uses not specified (1985) | -- | -- | -- | -- | -- | 4,731 | -- | 4,731 |
| Miscellaneous, water-washed: |  |  |  |  |  |  |  |  |
| Gypsum products, pesticides and related products, waterproofing and sealing, fertilizers, other uses not specified | -- | -- | 57,127 | 57,127 | -- | -- | 100,181 | 100,181 |
| Undistributed | 19,873 | 30,032 | 220 | 50,125 | 20,805 | 49,337 | 90 | 70,232 |
| **Total** | **580,891** | **640,094** | **3,947,214** | **5,168,199** | **611,929** | **470,508** | **4,024,229** | **5,106,661** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Exports: | | | | | | | | |
| Paint | 126 | -- | 83,480 | 83,606 | 77,883 | -- | 80,438 | 108,821 |
| Paper coating | -- | -- | 941,417 | 941,417 | 23,297 | -- | 766,392 | 789,689 |
| Paper filling | 134 | -- | 217,242 | 217,376 | 8,206 | -- | 137,049 | 145,255 |
| Plastics | 21 | -- | 22,985 | 22,956 | -- | -- | 19,223 | 19,223 |
| Refractories | 110 | 95,000 | 823 | 95,988 | -- | 188,640 | 281 | 188,921 |
| Rubber | 24 | -- | 785 | 809 | 235 | -- | 885 | 1,120 |
| Undistributed | 10,568 | -- | 17,460 | 28,023 | 18,018 | -- | 18,002 | 36,015 |
| Total | 10,978 | 95,000 | 1,234,142 | 1,340,120 | 127,684 | 188,640 | 972,270 | 1,288,544 |
| Grand total | 591,869 | 735,094 | 5,181,356 | 6,508,319 | 789,563 | 609,148 | 4,996,499 | 6,345,206 |

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Includes high-temperature calcined.

[2] Includes low-temperature calcined and delaminated.

## Table 9.—South Carolina kaolin sold or used by producers, by kind

| Kind | 1984 | | 1985 | |
|---|---|---|---|---|
| | Short tons | Value | Short tons | Value |
| Air-float[1] | 530,208 | $32,188,917 | 504,330 | $31,670,613 |
| Unprocessed | 246,359 | 1,215,170 | 362,482 | 3,638,725 |
| Total | 776,567 | 33,404,087 | 866,812 | 35,309,338 |

[1] Includes water-washed.

## Table 10.—South Carolina kaolin sold or used by producers, by kind and use

(Short tons)

| Kind and use | 1984 | 1985 |
|---|---|---|
| Air-float:[1] | | |
| Adhesives | 16,751 | 14,528 |
| Animal feed and pet waste absorbent | 6,844 | 5,333 |
| Ceramics[2] | 5,843 | 13,542 |
| Fertilizers, pesticides and related products | 19,300 | 33,855 |
| Fiberglass | 82,149 | 67,095 |
| Paint | 365 | 364 |
| Paper coating and filling | 1,488 | 1,843 |
| Plastics | 12,351 | 13,051 |
| Rubber | 204,627 | 188,945 |
| Refractories[3] | 9,318 | 30,052 |
| Other uses[4] | 108,514 | 85,495 |
| Exports[5] | 62,658 | 50,227 |
| Total | 530,208 | 504,330 |
| Unprocessed: Face brick and other uses | 246,359 | 362,482 |
| Grand total | 776,567 | 866,812 |

[1] Includes water-washed.
[2] Includes floor and wall tile, pottery, and roofing granules.
[3] Includes refractory calcines and grogs; refractory mortar and cement; high-alumina refractories; and firebrick, blocks and shapes.
[4] Includes animal oil, catalysts (oil-refining); chemical manufacturing, ink, medical, sewer pipe, and unknown uses.
[5] Includes ceramics, adhesives, paper filling, pesticides and related products, and rubber.

### Table 11.—Kaolin sold or used by producers in the United States, by use

(Short tons)

| Use | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Air-float | Unprocessed[1] | Water-washed[2] | Total | Air-float | Unprocessed[1] | Water-washed[2] | Total |
| Domestic: | | | | | | | | |
| Adhesives | 26,307 | -- | 66,733 | 93,040 | 21,941 | -- | 75,632 | 97,573 |
| Aluminum sulfate and other chemicals | -- | 327,497 | 10,544 | 338,041 | 243 | 202,424 | 3,017 | 205,684 |
| Animal feed | 6,861 | -- | 5,526 | 12,387 | 5,421 | -- | 5,686 | 11,107 |
| Brick, common and face | 5,213 | 319,340 | -- | 324,553 | 6,692 | 487,694 | -- | 494,386 |
| Catalysts (oil- and gas-refining) | 114,799 | 30,000 | 115,854 | 260,653 | 110,864 | 2,100 | 106,970 | 219,934 |
| Cement, portland | -- | 134,240 | 1,336 | 135,576 | -- | 133,977 | 1,140 | 135,117 |
| China and dinnerware | 31,767 | 1,399 | 1,240 | 34,406 | 13,908 | 1,453 | 729 | 16,090 |
| Crockery and other earthenware | W | -- | W | W | W | -- | -- | W |
| Electrical porcelain | 26,871 | -- | -- | 26,871 | 24,810 | -- | 312 | 25,122 |
| Fertilizers[3] | 11,300 | -- | 2,986 | 14,286 | 26,165 | -- | 2,937 | 29,102 |
| Fiberglass, mineral wool and other insulation | 212,174 | -- | 66,607 | 278,781 | 223,472 | -- | 80,079 | 303,551 |
| Firebrick, blocks and shapes | 7,814 | 4,643 | -- | 12,457 | 5,713 | 936 | 4 | 6,653 |
| Floor and wall tile; ceramic glazes, glass, enamels | 30,477 | 2,820 | -- | 33,297 | 18,571 | -- | -- | 18,571 |
| Flue linings, high-alumina brick and specialties | 20,000 | 47,818 | -- | 67,818 | 22,807 | 92,191 | -- | 114,998 |
| Foundry sand | 869 | -- | 41 | 910 | 925 | -- | 39 | 964 |
| Grogs and calcines, refractory | 4,886 | 417,062 | -- | 421,948 | 4,790 | 286,034 | -- | 290,824 |
| Gypsum products and wallboard | 8,324 | 7,249 | 2,759 | 18,332 | 4,721 | -- | 3,696 | 8,417 |
| Ink | W | -- | W | W | W | -- | W | W |
| Kiln furniture, refractory and mortar cement | 17,662 | 30,032 | -- | 47,694 | 45,195 | 49,337 | -- | 94,532 |
| Linoleum and asphalt tile | 14,098 | -- | 7,000 | 21,098 | 27,183 | -- | 6,000 | 33,183 |
| Medical, pharmaceutical, cosmetic | 1,244 | -- | 1,894 | 3,138 | 2,408 | -- | 1,396 | 3,804 |
| Paint | 14,679 | 849 | 214,475 | 230,003 | 14,099 | 3,938 | 181,643 | 199,680 |
| Paper coating | 8,827 | -- | 2,465,748 | 2,474,575 | -- | -- | 2,266,846 | 2,266,846 |
| Paper filling | 90,972 | -- | 893,799 | 984,771 | 120,596 | -- | 1,052,582 | 1,173,178 |
| Pesticides and related products | 8,073 | 31,750 | 2,458 | 42,281 | 7,848 | 15,344 | 44,037 | 67,229 |
| Plastics | 14,751 | -- | 44,160 | 58,911 | 18,699 | -- | 35,414 | 54,113 |
| Pottery | 4,568 | 699 | 1,712 | 6,979 | 13,159 | 726 | 1,546 | 15,431 |
| Roofing granules | 19,288 | -- | 4,152 | 23,440 | 22,779 | -- | 1,000 | 23,779 |
| Roofing and structural tile | 353 | -- | -- | 353 | 371 | -- | -- | 371 |
| Rubber | 229,430 | -- | 65,139 | 294,569 | 230,507 | -- | 83,484 | 313,991 |
| Sanitary ware | 109,912 | 11,891 | 51 | 121,854 | 124,095 | 12,353 | 730 | 137,178 |
| Waterproofing and sealing | W | -- | W | W | -- | -- | W | W |
| Miscellaneous | 36,361 | 16,131 | 60,713 | 113,205 | 54,210 | 7,653 | 68,528 | 130,391 |
| Total | 1,077,880 | 1,383,420 | 4,034,927 | 6,496,227 | 1,172,192 | 1,296,160 | 4,023,447 | 6,491,799 |

See footnotes at end of table.

## Table 11.—Kaolin sold or used by producers in the United States, by use —Continued

(Short tons)

| Use | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Air-float | Unprocessed[1] | Water-washed[2] | Total | Air-float | Unprocessed[1] | Water-washed[2] | Total |
| Exports: | | | | | | | | |
| Ceramics | 3,551 | -- | -- | 3,551 | 3,387 | -- | 2,381 | 5,768 |
| Foundry sand, grogs and calcines; other refractories | -- | 145,000 | -- | 145,000 | 11,293 | 141,135 | 281 | 152,709 |
| Paint | 126 | -- | 33,480 | 33,606 | 466 | -- | 112,007 | 112,473 |
| Paper coating | -- | -- | 941,417 | 941,417 | 23,297 | -- | 766,392 | 789,689 |
| Paper filling | 371 | -- | 217,242 | 217,613 | 8,448 | -- | 136,871 | 145,319 |
| Plastics | 21 | -- | 22,935 | 22,956 | -- | -- | 19,223 | 19,223 |
| Rubber | 47,968 | -- | 785 | 48,753 | 38,848 | -- | 885 | 39,733 |
| Miscellaneous | 23,374 | -- | 20,172 | 43,546 | 17,802 | -- | 18,807 | 36,609 |
| Total | 75,411 | 145,000 | 1,236,031 | 1,456,442 | 103,541 | 141,135 | 1,056,847 | 1,301,523 |
| Grand total | 1,153,291 | 1,528,420 | 5,270,958 | 7,952,669 | 1,275,733 | 1,437,295 | 5,080,294 | 7,793,322 |

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."

[1] Includes high-temperature calcined.

[2] Includes low-temperature calcined and delaminated.

[3] Includes soil conditioners and mulches.

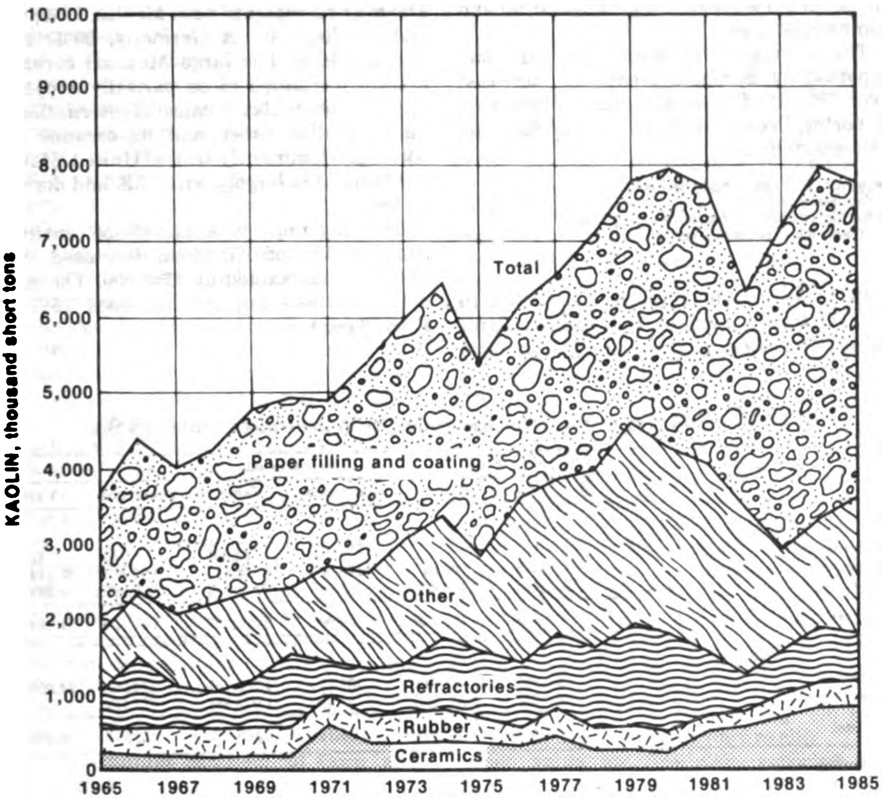

**Figure 1.—Kaolin sold or used by domestic producers for specified uses.**

### BALL CLAY

Reported production of domestic ball clay increased about 4% to nearly 902,000 tons valued at about $35 million. Tennessee provided 74% of the Nation's output, followed, in order of production, by Kentucky, Mississippi, Texas, and Maryland.[2] Production, as in 1984, either increased or remained relatively unchanged in all States. The principal ball clay markets were ceramics, chiefly dinnerware, pottery, sanitary ware, and wall tile. Domestic producers also enjoyed a robust export market, despite a strong U.S. dollar, usually over 20% of total production. Continued recovery of the domestic construction industry, spurred on by declining interest rates and the improved overall economy during the year, increased the demand for ball clays.

Ball clay is defined as a plastic, white-firing clay used principally for bonding in ceramic ware. The clay is of sedimentary origin and consists mainly of the clay mineral kaolinite and sericite mica.

Industrywide enlargements, modernizations, and/or mergers started to occur again. H. C. Spinks Clay Co. announced plans to open a new ball clay mine in the Paris, TN, area and began expansion of its facilities to ship water-slurried clays by tank cars. Spinks previously only produced dry-processed clay. Most of the major ball clay producers were currently either producing or planning to produce slurried clays. American Olean Tile Co., a subsidiary of National Gypsum Co., announced plans for a $13 million expansion of its Lansdale, PA, manufacturing facilities, to be completed by mid-1986. The enlargement was to include state-of-the-art ceramic tile manufacturing equipment capable of producing a more versatile product line to meet the ever changing consumer demand in sizes and shapes of glazed floor tile for residential and commercial uses.

The average unit value for ball clay reported by domestic producers increased over 7% to $38.49. Chemical Marketing Reporter, December 31, 1985, listed ball clay prices as follows:

| | |
|---|---|
| Domestic, air-floated, bags, carload lots, Tennessee, per ton | $49.00 |
| Domestic, crushed, moisture-repellent, bulk carload lots, Tennessee, per ton | 24.00 |

Ball clay exports increased nearly 24% to 204,000 tons valued at $6.8 million. Unit value decreased slightly to $33.21 from $39.37 per ton in 1984. Shipments were made to 30 countries, the same as in 1984. The major recipients were Mexico, 60%; the Federal Republic of Germany, 20%; and Canada, 16%. The large Mexican ceramic market continued to be partially supplied by its domestic clay because of international financial difficulties, and its ceramic exports, prodominantly to the United States, are fabricated largely with U.S. and domestic clays.

Ball clay imports, again almost entirely from the United Kingdom, decreased 36% to 1,269 tons valued at $148,000. The unit value of these imports increased 15% to $116.63 per ton.

## Table 12.—Ball clay sold or used by producers in the United States, by State

| State | Air-float | | Unprocessed | | Total | |
|---|---|---|---|---|---|---|
| | Short tons | Value | Short tons | Value | Short tons | Value |
| 1984 | | | | | | |
| California | -- | -- | 246 | $2,958 | 246 | $2,958 |
| Tennessee[r] | 479,353 | $17,000,841 | [1]125,560 | [1]3,523,445 | 604,913 | 20,524,286 |
| Other[r] | [2]251,090 | [2]10,118,879 | [2]11,175 | [2]453,536 | 262,265 | 10,572,415 |
| Total[r] | 730,443 | 27,119,720 | 136,981 | 3,979,939 | 867,424 | 31,099,659 |
| 1985 | | | | | | |
| Tennessee | [1]502,301 | [1]20,463,910 | 162,254 | 4,136,759 | 664,555 | 24,600,669 |
| Other[3] | 203,634 | 9,036,635 | 33,490 | 1,070,953 | 237,124 | 10,107,588 |
| Total | 705,935 | 29,500,545 | 195,744 | 5,207,712 | 901,679 | 34,708,257 |

[r] Revised.

[1] Includes water-slurried.

[2] Includes Kentucky, Maryland, Mississippi, and Texas

[3] Includes Kentucky, Maryland, Mississippi, and New York.

## Table 13.—Ball clay sold or used by producers in the United States, by use

(Short tons)

| Use | 1984[r] | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Air-float[1] | Unprocessed | Total | Air-float[1] | Unprocessed | Total |
| Adhesives | W | -- | W | W | -- | W |
| Animal feed | W | W | 8,585 | W | W | 13,943 |
| Crockery and other earthenware | W | -- | W | W | W | W |
| Drilling mud | W | -- | W | W | -- | W |
| Electrical porcelain | 18,787 | 7,059 | 25,846 | 42,240 | -- | 42,240 |
| Fiberglass and catalysts (oil-refining) | W | -- | W | W | W | W |
| Fine china and dinnerware | 35,704 | -- | 35,704 | 27,491 | -- | 27,491 |
| Firebrick, blocks and shapes | W | W | W | W | W | W |
| Floor and wall tile | 92,115 | 35,981 | 128,096 | 97,586 | 31,466 | 129,052 |
| Glazes, glass, enamels | 2,461 | 273 | 2,734 | 1,606 | -- | 1,606 |
| Grogs and calcines, high-alumina, mortar and cement, other refractories | 93,752 | 8,207 | 101,959 | 91,791 | 13,837 | 105,628 |
| Kiln furniture | 1,789 | -- | 1,789 | 1,708 | -- | 1,708 |
| Paper coating and filling | 11,062 | -- | 11,062 | 5,532 | -- | 5,532 |
| Pesticides and related products | W | -- | W | W | -- | W |
| Pottery | 180,759 | 17,022 | 197,781 | 140,375 | 63,118 | 203,493 |
| Rubber | W | -- | W | W | W | W |
| Sanitary ware | 92,683 | 45,379 | 138,062 | 114,788 | 38,309 | 153,097 |
| Miscellaneous | 119,061 | 19,649 | [2]130,175 | 130,540 | 23,479 | [2]140,076 |
| Exports | 82,270 | 3,411 | 85,681 | 52,278 | 25,535 | 77,813 |
| Total | 730,443 | 136,981 | 867,424 | 705,935 | 195,744 | 901,679 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Total" and/or "Miscellaneous."

[1] Includes water-slurried.

[2] Incomplete total; difference included in totals for specific uses.

## FIRE CLAY

Fire clay sold or used by domestic producers decreased 15% to about 974,000 tons valued at $18.0 million. Fire clay is defined as detrital material, either plastic or rocklike, containing low percentages of alkalies, iron oxide, lime, and magnesia to enable the material to withstand temperatures of 1,500° C or higher. It is basically kaolinite but usually contains other materials such as ball clay, bauxite clay, diaspore, and shale. Fire clay commonly occurs as underclay below coal seams and is generally used for refractories.

Industrywide expansions and modernizations were slowed during the year, while acquisitions and/or mergers were commonplace. Plants continued to be either operating intermittently or on minimal production schedules. The clay refractory industry has been in a period of low production since 1982, reflecting lower demand by major consumers—steel, nonferrous metals, ceramics, glass, and minerals processing. The fire clay industry's problems were further exacerbated by the technological changes in steelmaking processes that require more higher alumina-based refractories, either direct-fired or specialties, which contain less fire clay. These uncertainties in the fire clay industry resulted in the divestiture of refractory manufacturing operations of Kaiser Aluminum & Chemical Corp. and Allied-Signal Inc. Kaiser sold most of its North American clay and nonclay refractory manufacturing and administrative facilities in California, Indiana, Missouri, Ohio, and Ontario, Canada, to the newly formed employee-owned National Refractories and Minerals Corp., a company organized by the former management of Kaiser Refractories and Kelso and Co., an investment banker, for an undisclosed sum. The Allied-Signal's divestiture included its North American Refractories Co. (NARCO), which, subject to financing, was purchased by Kirtland Capital Corp. and members of NARCO'S management. NARCO, headquartered in Cleveland, OH, operates 10 manufacturing facilities in the United States and Canada.

An exception to the industry malaise was the $8 million expansion by Didier-Taylor Refractories Corp. of its Cincinnati, OH, plant. The expansion included a one-third increase of the existing area to boost production of continuous steel casting refractories, a clay-derived mullitic and/or zirconia-based material.

Exports of fire clay decreased about 3% to 223,000 tons valued at $17.8 million. The unit value of exported clay increased 6% to $79.86 indicating that, despite a decrease in exports, the trend of shipping a higher percentage of higher quality material continued. Fire clay was exported to 24 countries, a decrease of 7 from that of 1984. Japan received 27%, while Belgium-Luxembourg, Canada, and Mexico received 24%, 13%, and 11%, respectively. No imports were again reported for fire clay.

Unit value for fire clay, reported by producers, ranged from about $2.00 to $30.00 per ton. The average unit value remained relatively unchanged at $18.46 per ton.

Table 14.—Fire clay[1] sold or used by producers in the United States, by State

| State | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Short tons | Value | Short tons | Value |
| Alabama | 144,267 | $3,488,675 | 130,000 | $3,217,200 |
| Colorado | 14,795 | 169,403 | 20,384 | 166,330 |
| Missouri | 427,681 | 8,540,260 | 283,697 | 5,072,854 |
| Montana | -- | -- | 508 | 2,641 |
| New Jersey | 12,018 | 211,000 | 10,166 | 250,079 |
| New Mexico | 1,818 | 11,080 | 2,767 | 16,547 |
| Ohio | 303,827 | 5,004,394 | 241,045 | 4,442,140 |
| Pennsylvania | 60,507 | 305,196 | 80,610 | 772,095 |
| Texas | 24,251 | 189,894 | 21,196 | 156,190 |
| Utah | 411 | 8,289 | 500 | 8,300 |
| Washington | 6,000 | W | -- | -- |
| West Virginia | 98,064 | 2,794,824 | 98,064 | 2,794,824 |
| Other[2] | 51,840 | 422,871 | 85,482 | 1,092,536 |
| Total | 1,144,974 | 21,140,886 | 974,414 | 17,986,736 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Refractory uses only.

[2] Includes California, Idaho, Indiana (1984), Kentucky, and value indicated by symbol W.

## BENTONITE

Bentonite production decreased over 7% to about 3.2 million tons valued at almost $102 million. A 12% decrease in production of swelling bentonite in Wyoming, the largest producing State, accounted for most of this decrease. Domestic production for drilling mud, foundry sand, and pelletizing iron ore all declined.

Bentonite was again produced in 13 States. The high-swelling or sodium bentonites continued to be produced chiefly, in descending order, in Wyoming and Montana. The calcium or low-swelling bentonites continued to be produced in the other States. Calcium bentonite production in Mississippi is suitable for the production of both absorbent and acid-activated products.

The major western and southern bentonite producers continued to cancel or defer planned enlargements and/or modernizations. Most plants continued sporadic operation at new lower production levels. The industry depression continued to be caused by lower oil- and gas-drilling activities during the year, exacerbated by the downturn in the steel and foundry industries. These three industries traditionally consume about 90% of the total domestic output. Some drilling activity increased in the first three quarters of the year but slowed again at yearend.

Exceptions to industry retrenchments were largely confined to the calcium bentonite or southern bentonite producers. American Colloid Co., Skokie, IL, completed a $3.5 million expansion at its Aberdeen, MS, facility, to produce acid-activated clays for purifying and filtering edible and nonedible oils and juices. In a novel barge loading scheme, to increase export competitiveness by lowering transportation costs, American Colloid began using an abandoned bridge over the Tennessee-Tombigbee Waterway to load barges with granular product as a first leg in shipping clay to Asian markets. The Belen City Council, Belen, NM, approved the issue of industrial revenue bonds for the maintenance of a city-owned facility, operated by the lessee, United Desiccants Div. of United Catalysts, to manufacture and market clay desiccants used in shipping moisture-sensitive electronic and photographic components.

The Office of Surface Mining granted the State of Wyoming $30 million to reclaim about 100 sodium bentonite mines on 5,000 acres in Crook County, northern Wyoming. The funds were also to be used for reclaiming several other minesites, one of which was a shale mine.

On December 31, 1985, Chemical Marketing Reporter quoted domestic bentonite, 200 mesh, bags, carload lots, f.o.b. mines, as unchanged at $43.50 per ton. The average unit value reported by domestic producers increased 10% to $31.90 per ton. Per-ton values reported in the various producing States ranged from $14 to over $70, but the average value reported by the larger producers was near the Montana average of about $32.

Bentonite exports increased nearly 14% to 640,000 tons valued at almost $45.0 million. The unit value of exported bentonite decreased nearly 13% to $70.27 per ton; this was attributed to higher percentages of lower cost iron ore pelletizing grades shipped over the costlier drilling-mud and foundry grades exported. Domestic bentonite producers continued to face increased competition in foreign markets; in particular, the Canadian iron ore markets where Mediterranean bentonites have made inroads into an area traditionally served by domestic producers.

Bentonite was exported to 67 countries, a decrease of 4 from that of 1984. The major recipients were Canada, 49%; Japan, 15%; the Netherlands and Singapore, 4% each; and the United Kingdom, 3%. Domestic bentonite producers reported their exports were foundry sand, 39%; drilling mud, 27%; and other, 33%.

Bentonite imports, consisting mostly of both untreated clay and chemically or artificially activated material, increased over 35% to nearly 23,000 tons. The chemically activated category, slowly increasing in quantity for the past several years, increased over 35% to 14,443 tons valued at $3.7 million, primarily because of increased shipments from Mexico, which were 64% more than those of 1984. The chemically activated bentonite was imported from six countries, one less than in 1984, with Mexico supplying 74%; Canada, 22%; the United Kingdom, 3%; and the Federal Republic of Germany, Japan, and Switzerland, the remaining 1%.

## Table 15.—Bentonite sold or used by producers in the United States, by State

| State | Nonswelling | | Swelling | | Total | |
|---|---|---|---|---|---|---|
| | Short tons | Value | Short tons | Value | Short tons | Value |
| **1984** | | | | | | |
| Arizona | 20,466 | $300,618 | 28 | $835 | 20,494 | $301,453 |
| California | 69,098 | 5,099,773 | 25,445 | 1,593,017 | 94,543 | 6,692,790 |
| Colorado | 139 | 1,896 | 11 | 204 | 150 | 2,100 |
| Kansas | -- | -- | 20,000 | 750,000 | 20,000 | 750,000 |
| Mississippi[r] | 227,625 | 6,335,218 | -- | -- | 227,625 | 6,335,218 |
| Montana[r] | -- | -- | 212,223 | 5,615,989 | 212,223 | 5,615,989 |
| Nevada | -- | -- | 20,092 | 1,191,011 | 20,092 | 1,191,011 |
| Texas | 35,850 | W | 26,495 | W | 62,345 | 925,694 |
| Utah | -- | -- | 3,994 | 139,810 | 3,994 | 139,810 |
| Wyoming[r] | -- | -- | 2,414,905 | 66,686,549 | 2,414,905 | 66,686,549 |
| Other[r] | [1]158,171 | [1]5,591,798 | [2]203,398 | [2]5,928,019 | 361,569 | [3]10,594,123 |
| Total[r] | 511,349 | 17,379,308 | 2,926,591 | 81,905,434 | 3,437,940 | 99,284,737 |
| **1985** | | | | | | |
| Arizona | 31,924 | 713,571 | 900 | 27,000 | 32,824 | 740,571 |
| California | 92,379 | 6,681,408 | 20,511 | 1,349,102 | 112,890 | 8,030,505 |
| Colorado | 74 | 740 | 6 | 60 | 80 | 800 |
| Kansas | -- | -- | 24,000 | 888,000 | 24,000 | 888,000 |
| Mississippi | 197,531 | 6,106,229 | -- | -- | 197,531 | 6,106,229 |
| Montana | -- | -- | 254,398 | 8,232,639 | 254,398 | 8,232,639 |
| Nevada | -- | -- | 79,861 | 3,775,947 | 79,861 | 3,775,947 |
| Texas | 30,791 | 637,227 | 15,971 | 212,470 | 46,762 | 849,697 |
| Utah | -- | -- | 14,006 | 420,721 | 14,006 | 420,721 |
| Wyoming | -- | -- | 2,116,085 | 63,064,643 | 2,116,085 | 63,064,643 |
| Other | [1]145,250 | [1]3,250,695 | [2]171,598 | [2]6,565,338 | 316,848 | 9,816,033 |
| Total | 497,949 | 17,389,865 | 2,697,331 | 84,585,920 | 3,195,280 | 101,925,785 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes Alabama, Idaho, and Louisiana (1984).

[2] Includes Idaho and South Dakota.

[3] Incomplete total; difference included with individual State totals.

## Table 16.—Bentonite sold or used by producers in the United States, by use

(Short tons)

| Use | 1984[r] | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Nonswelling | Swelling | Total | Nonswelling | Swelling | Total |
| Domestic: | | | | | | |
| Adhesives | -- | 6,757 | 6,757 | 2,000 | 6,938 | 8,938 |
| Animal feed | 49,811 | 136,321 | 186,132 | 38,265 | 92,219 | 130,484 |
| Catalysts (oil-refining) | 8,763 | -- | 8,763 | 5,748 | 2,470 | 8,218 |
| Cement, portland | -- | W | W | -- | W | W |
| Drilling mud | 14,878 | 1,346,191 | 1,361,069 | 17,913 | 1,168,728 | 1,186,641 |
| Filtering, clarifying, decolorizing: | | | | | | |
| Animal oils, mineral oils and greases, and desiccants | 1,074 | 5,119 | 6,193 | 7,300 | 3,071 | 10,371 |
| Vegetable oils | -- | -- | -- | 29,200 | -- | 29,200 |
| Foundry sand | 227,886 | 520,177 | 748,063 | 206,388 | 522,199 | 728,587 |
| Glazes, glass, enamels | -- | W | W | -- | W | W |
| Medical, pharmaceutical, cosmetic | -- | 5,081 | 5,081 | -- | 3,968 | 3,968 |
| Oil and grease absorbents | 100,951 | 45 | 100,996 | 34,448 | 45 | 34,493 |
| Paint | -- | 10,852 | 10,852 | -- | 7,161 | 7,161 |
| Pelletizing (iron ore) | -- | 404,493 | 404,493 | -- | 290,567 | 290,567 |
| Pesticides and related products | 425 | 10,268 | 10,693 | 897 | 235 | 1,132 |
| Waterproofing and sealing | 1,597 | 72,795 | 74,392 | 3,432 | 119,876 | 123,308 |
| Miscellaneous[1] | 103,016 | 67,524 | 170,540 | 126,302 | 79,334 | 205,636 |
| Total | 508,401 | 2,585,623 | 3,094,024 | 471,893 | 2,296,811 | 2,768,704 |
| Exports: | | | | | | |
| Drilling mud | -- | 153,188 | 153,188 | -- | 117,130 | 117,130 |
| Foundry sand | 1,310 | 161,038 | 162,348 | 24,978 | 142,420 | 167,398 |
| Other[2] | 1,638 | 26,742 | 28,380 | 1,078 | 140,970 | 142,048 |
| Total | 2,948 | 340,968 | 343,916 | 26,056 | 400,520 | 426,576 |
| Grand total | 511,349 | 2,926,591 | 3,437,940 | 497,949 | 2,697,331 | 3,195,280 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."

[1] Chemical manufacturing; fiberglass; firebrick, blocks and shapes; gypsum products; mineral wool and insulation; paper coating and filling; pet waste absorbents; plastics; rubber; ink; uses not specified; and data indicated by symbol W.

[2] Includes animal feed, face brick, paint, plastics, waterproofing and sealing, and uses not specified.

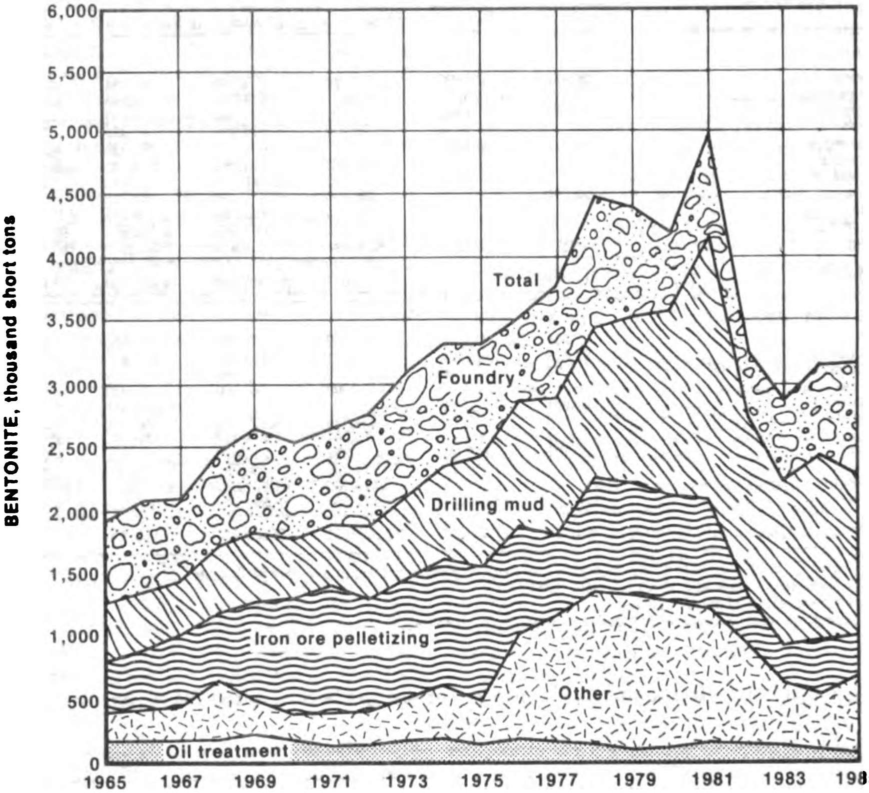

**Figure 2.—Bentonite sold or used by domestic producers for specified uses.**

## FULLER'S EARTH

Production of fuller's earth increased 8% to almost 2.1 million tons valued at about $129 million. This increase in production, after the first reported decline in 1984, marks a return to the upward trend in production that the industry has enjoyed for over 10 years. Generally an increase in absorbent-grade clay production was partially offset by a 16% decline in attapulgite-gelling clay production in Florida. The average unit value increased slightly to $62.87 per ton. Production was reported from operations in 10 States, or 1 less than in 1984. The two top producing States, Florida and Georgia, accounted for 48% of domestic production. All States, except Florida, Missouri, and South Carolina, showed gains in production.

Increases in consumption occurred in oil and grease absorbents while consumption of pet waste absorbents declined.

Fuller's earth is defined as a nonplastic clay or claylike material, usually high in magnesia, which has adequate absorbing, decolorizing, and purifying properties. Sepiolite-type clays are also included for statistical convenience.

Production from the region that includes Attapulgus, Decatur County, GA, and Quincy, Gadsden County, FL, is composed predominantly of the lath-shaped amphibole-like clay mineral attapulgite. Most of the fuller's earth produced in other areas of the United States contains varieties of montmorillonite.

Industrywide enlargements, modernizations, acquisitions, and/or merger plans, slowed because of the economic downturn in the past 2 years, were beginning to be activated again. Oil-Dri Corp., Chicago, IL, finalized the purchase of Anschutz Mining Corp., near Ochlocknee, GA, for $1.75 million in cash and notes. The newly acquired assets included buildings, equipment, land,

and mineral leases all situated directly adjacent to Oil-Dri's plant and mining operations. A stock offering was also announced by Oil-Dri to raise capital for expanding and improving both Ochlocknee facilities. The projected growth of the premium segment of the cat litter market and Oil-Dri's emphasis on developing agriculturally related and specialty absorbents were cited for the additional reserves and plant capacity. In another acquisition, United States Borax & Chemical Corp., Los Angeles, CA, a subsidiary of The Rio Tinto Zinc Corp. PLC of the United Kingdom, purchased the assets of Pennsylvania Glass Sand Corp. (PGS), Berkeley Springs, WV, a subsidiary of ITT Corp., for $80 million. The purchase included PGS' Floridin Co., a major Florida producer of attapulgite-type fuller's earth used primarily in absorbent, thickening, and drilling-mud markets. Floridin also completed doubling its production capacity for its specially processed finely ground attapulgite used as thickening and suspending agents in paint, wallboard, adhesives, and asphalt coating and/or sealants applications at its fully automated Quincy, FL, plant. Floridin and the Seaboard Coast Line successfully developed a double-tier stacking arrangement for shipping up to 55 tons of bagged clay in a boxcar. Previously, single pallets, weighing up to 30 tons, were permitted in a 50-foot boxcar. The novel shipping techniques should increase the competitiveness of rail shipments.

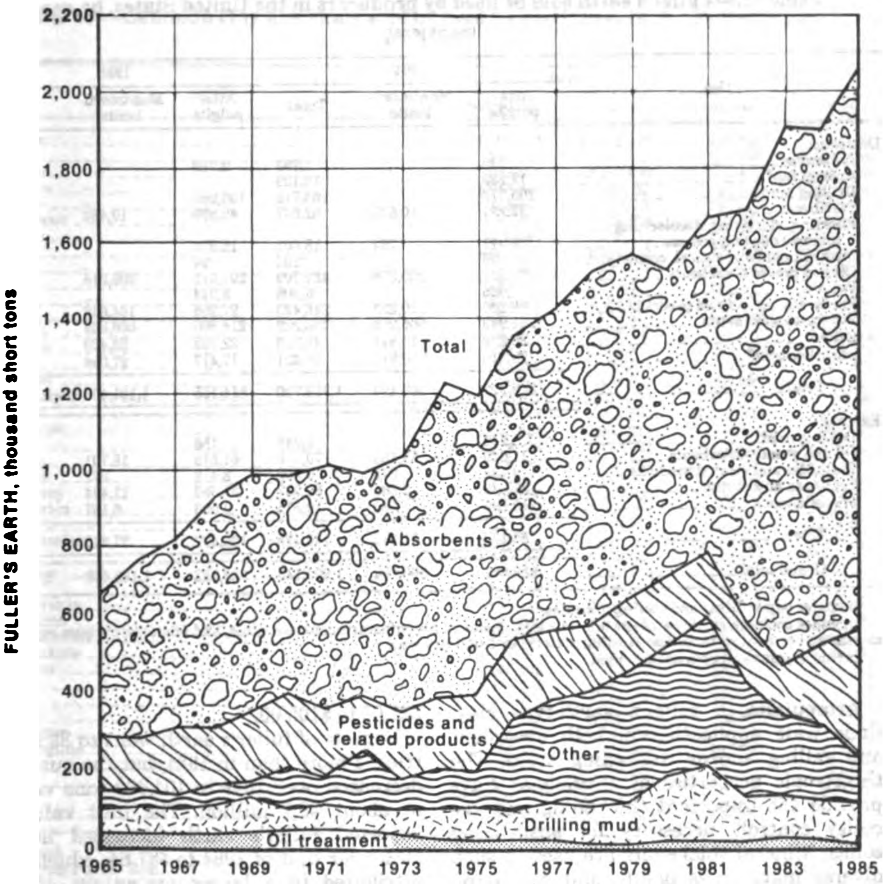

**Figure 3.—Fuller's earth sold or used by domestic producers for specified uses.**

## Table 17.—Fuller's earth sold or used by producers in the United States, by State

| State | Attapulgite | | Montmorillonite | | Total | |
|---|---|---|---|---|---|---|
| | Short tons | Value | Short tons | Value | Short tons | Value |
| **1984** | | | | | | |
| Florida | 459,502 | $30,785,278 | -- | -- | 459,502 | $30,785,278 |
| Georgia | 363,669 | 23,601,595 | 205,414 | $8,812,997 | 569,083 | 32,414,592 |
| Virginia | -- | -- | 24,000 | 2,400,000 | 24,000 | 2,400,000 |
| Other | [1]115,190 | [1]6,371,947 | [2]731,370 | [2]46,417,069 | 846,560 | 52,789,016 |
| Total | 938,361 | 60,758,815 | 960,784 | 57,630,066 | 1,899,145 | 118,388,881 |
| **1985** | | | | | | |
| Florida | 387,076 | 29,451,978 | -- | -- | 387,076 | 29,451,978 |
| Georgia | 396,737 | 25,333,176 | 206,296 | 9,294,984 | 593,033 | 34,628,160 |
| Virginia | -- | -- | 28,000 | 2,940,000 | 28,000 | 2,940,000 |
| Other | [1]146,819 | [1]8,293,241 | [2]904,353 | [2]54,155,576 | 1,051,172 | 62,448,817 |
| Total | 930,632 | 63,078,395 | 1,138,649 | 66,390,560 | 2,059,281 | 129,468,955 |

[1] Includes Illinois, Nevada (1984), and Texas.
[2] Includes Illinois, Mississippi, Missouri, Nevada (1985), South Carolina, Tennessee, and Utah (1984).

## Table 18.—Fuller's earth sold or used by producers in the United States, by use

(Short tons)

| Use | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Attapulgite | Montmorillonite | Total | Attapulgite | Montmorillonite | Total |
| Domestic: | | | | | | |
| Adhesives | 1,798 | -- | 1,798 | 2,740 | -- | 2,740 |
| Animal feed | 12,139 | -- | 12,139 | -- | -- | -- |
| Drilling mud | 105,716 | -- | 105,716 | 106,980 | -- | 106,980 |
| Fertilizers | 52,291 | 10,576 | 62,867 | 46,899 | 10,482 | 57,381 |
| Filtering, clarifying, decolorizing mineral oils and greases | 18,017 | 784 | 18,801 | 15,321 | -- | 15,321 |
| Medical, pharmaceutical, cosmetic | 105 | -- | 105 | 94 | -- | 94 |
| Oil and grease absorbents | 209,831 | 220,878 | 430,709 | 291,612 | 309,015 | 600,627 |
| Paint | 6,606 | -- | 6,606 | 3,244 | -- | 3,244 |
| Pesticides and related products | 96,200 | 120,223 | 216,423 | 92,266 | 164,546 | 256,812 |
| Pet waste absorbents | 291,943 | 506,279 | 798,222 | 214,800 | 566,869 | 781,669 |
| Other[1] | 25,872 | 19,841 | 45,713 | 22,782 | 23,400 | 46,182 |
| Miscellaneous[2] | 28,710 | 30,911 | 59,621 | 17,417 | 27,094 | 44,511 |
| Total | 849,228 | 909,492 | 1,758,720 | 814,155 | 1,101,406 | 1,915,561 |
| Exports: | | | | | | |
| Drilling mud | 1,246 | -- | 1,246 | 156 | -- | 156 |
| Oil and grease absorbents | 41,020 | 38,138 | 79,158 | 61,518 | 18,701 | 80,219 |
| Pesticides and related products | 9,135 | 373 | 9,508 | 8,418 | 971 | 9,389 |
| Pet waste absorbents | 27,642 | 12,295 | 39,937 | 27,382 | 11,434 | 38,816 |
| Miscellaneous[3] | 10,090 | 486 | 10,576 | 9,003 | 6,137 | 15,140 |
| Total | 89,133 | 51,292 | 140,425 | 106,477 | 37,243 | 143,720 |
| Grand total | 938,361 | 960,784 | 1,899,145 | 920,632 | 1,138,649 | 2,059,281 |

[1] Includes paper filling and roofing granules.
[2] Includes common brick; catalysts (oil-refining); chemical manufacturing; glazes, glass, and enamels; gypsum products; mortar and cement refractories; plastics; pottery; and sanitary ware.
[3] Includes paint and uses not specified.

Attapulgite, a fuller's earth-type clay, finds wide application in both absorbent and gelling and/or thickening areas. The thixotropic properties of attapulgite clays provide the important thickening and viscosity controls necessary for suspending solids. Mineral thickeners are used in such diverse markets as paint, joint compound cement, and saltwater drilling muds.

Prices for attapulgite reported by producers ranged from $49.50 to $68.51 per ton; montmorillonite prices ranged from about $21.00 to $105.00.

Exports of fuller's earth went to 33 countries, 2 more than in 1984, but the quantity decreased over 10% to 104,000 tons valued at about $9.1 million. The unit value of exported fuller's earth increased nearly 10% over that of 1984 to $87.84, which was attributed to a larger percentage of the high-cost gelling and drilling-mud grades exported in 1985 compared with the absorbent grades shipped. The major recipients were Canada, 73%; the Netherlands, 17%;

and the United Kingdom, 3%. Imports of fuller's earth, usually nil, were 3,814 tons valued at about $153,000. Imports consisted of over 3,600 tons of drilling-mud attapulgite received at New Orleans, LA. All attapulgite previously used by the domestic drilling-mud companies was domestically produced clay. Continued imports of attapulgite for the already depressed drilling exploration market will probably result in further production cutbacks by the domestic suppliers.

## COMMON CLAY

Domestic sales or use of common clay and shale increased 6% to about 30.2 million tons valued at almost $132 million. Output rose above 5% in each of the States that produced over 1 million tons except for South Carolina. Texas, the major producing State, increased about 15%, which was largely attributed to the increased use of lightweight aggregates in road surfacing. The increase offset the decline in building construction rates because of its softening oil- and gas-based economy. Common clay and shale represented 67% of the quantity and 13% of the value of total domestic clay production. Domestic clay and shale are generally mined and used captively to fabricate or manufacture products. Less than 10% of the total output is usually sold. The average unit value for all common clay and shale produced in the United States and Puerto Rico decreased 3% to $4.37 per ton. The unit value ranged from $2 to over $20.

Table 19.—Common clay and shale sold or used by producers in the United States,[1] by State

| State | 1984 | | 1985 | |
|---|---|---|---|---|
| | Short tons | Value | Short tons | Value |
| Alabama | 1,523,073 | $8,379,481 | 1,630,739 | $7,962,196 |
| Arizona | 117,134 | 517,140 | 153,608 | 762,708 |
| Arkansas | 933,420 | 2,157,030 | 911,335 | 1,891,739 |
| California | 1,945,840 | 15,334,228 | 2,062,256 | 17,809,172 |
| Colorado | 293,347 | 1,939,506 | 282,411 | 1,575,560 |
| Connecticut | 99,078 | 564,620 | 106,033 | 631,873 |
| Florida | 279,947 | 824,512 | 248,680 | 779,176 |
| Georgia | 1,601,268 | 4,917,857 | 1,732,742 | 5,488,744 |
| Illinois | 253,381 | 939,966 | 265,467 | 876,123 |
| Indiana | 653,135 | 2,085,427 | 739,711 | 2,776,446 |
| Iowa | 623,169 | 2,694,651 | 503,298 | 2,449,931 |
| Kansas | 897,722 | 4,786,598 | 854,177 | 4,437,709 |
| Kentucky | 661,644 | 2,532,769 | 661,176 | 2,305,585 |
| Louisiana | 539,472 | 10,858,373 | 333,619 | 7,016,609 |
| Maine | 43,488 | 96,522 | 49,500 | 99,555 |
| Maryland | 346,963 | 1,483,631 | 336,085 | 1,646,991 |
| Massachusetts | 239,929 | 1,211,614 | 264,538 | 1,388,090 |
| Michigan | 1,320,774 | 5,051,586 | 1,477,309 | 5,513,822 |
| Mississippi | r1,045,938 | r3,981,311 | 850,706 | 3,292,143 |
| Missouri | 1,079,094 | 4,178,762 | 1,204,854 | 3,497,245 |
| Montana | 16,422 | 25,743 | 24,190 | 60,369 |
| Nebraska | 179,946 | 555,818 | 244,228 | 718,214 |
| New Jersey | 50,000 | 400,000 | 120,000 | 1,800,000 |
| New Mexico | 64,784 | 132,226 | 57,048 | 144,167 |
| New York | 543,368 | 2,434,776 | 699,764 | 3,129,207 |
| North Carolina | 2,280,634 | 7,911,093 | 2,611,455 | 8,533,367 |
| Ohio | 1,656,686 | 5,468,566 | 1,873,037 | 6,138,465 |
| Oklahoma | 979,291 | 2,498,178 | 996,522 | 2,337,657 |
| Oregon | 189,167 | 288,443 | 188,026 | 284,626 |
| Pennsylvania | 902,448 | 3,745,079 | 1,061,607 | 4,520,686 |
| Puerto Rico | 127,966 | 266,435 | 118,192 | 263,568 |
| South Carolina | 1,057,061 | 3,405,359 | 1,029,178 | 2,385,886 |
| South Dakota | 119,149 | 343,149 | 117,065 | 309,052 |
| Tennessee | 560,278 | 1,165,263 | 579,069 | 1,312,029 |
| Texas | 3,406,593 | 15,362,396 | 3,919,159 | 18,317,566 |
| Utah | 310,439 | 2,079,497 | 317,725 | 2,085,283 |
| Virginia | 687,968 | 3,603,785 | 786,295 | 4,036,908 |
| Washington | 285,961 | 1,598,120 | 242,914 | 1,402,107 |
| West Virginia | 283,328 | 615,084 | 233,269 | 547,627 |
| Wyoming | 213,350 | 1,234,381 | 185,917 | 1,081,562 |
| Other[2] | 115,492 | 422,688 | 95,421 | 324,908 |
| Total | r28,528,147 | r128,091,663 | 30,168,325 | 131,934,671 |

rRevised.

[1] Includes Puerto Rico.

[2] Includes Minnesota, New Hampshire, and North Dakota.

Common clay is defined as a clay or claylike material that is sufficiently plastic to permit ready molding and that vitrifies below 1,100° C. Shale is a sedimentary rock composed chiefly of clay minerals that has been both laminated and indurated while buried under other sediments. Clay and shale are used in the manufacture of structural clay products such as brick and drain tile, portland cement clinker, and expanded lightweight aggregates.

Increased production capacities, new plants, modernizations, acquisitions and/or mergers proceeded slowly during the year. The construction industry, the biggest user of heavy clay products, such as brick, lightweight aggregate, portland cement, sewer pipe, and tiles was moving along at a brisk pace. Large inventories accumulated during the winter months were worked off by the first quarter, and at midyear, the industry was experiencing heavy production, somewhat encouraged by declining interest rates. A notable exception to boom times was the declining construction rates in the depressed oil producing States of Texas, Louisiana, and Oklahoma.

In acquisitions, Jim Walter Corp., a large Tampa, FL, building supply and home building company, purchased Cherokee Brick of North Carolina Inc. and Sanford Brick Corp., also in North Carolina, for an undisclosed sum. The purchase, Walter's first of a brick plant, signals the company's move to further diversify its building supply line by adding brick. Cherokee, based in Raleigh, has a plant in Mancure, and Sanford Brick, based in Sanford, has plants in Sanford and Norwood and a Chatham County plant making specialty bricks of various sizes and colors. North Carolina is traditionally the largest brick producing State. In another move, Old Virginia Brick Co. (OVB) was acquired by a group of three entrepreneurs experienced in the brick industry. The company, in business since 1890, produces both wood-molded and extruded bricks at its Salem, VA, complex, near Roanoke. The new owners planned substantial changes in both plant operations and marketing strategies along with automation in administration and quality control.

Increases in production capacity were announced by Robinson Brick Co., Denver, CO; and Cloud Ceramics Inc., Concordia, KS, installed a new slug cutter to replace one that cut nearly 1 billion bricks. An oxygen enrichment scheme for gas firing its tunnel kilns was successfully completed by Watsontown Brick Co. at its Watsontown, PA, brickworks. The new firing scheme not only succeeded in reducing gas costs by over 20% but unexpectedly resulted in producing a more competitive, deeper, and uniformly colored red brick.

## CONSUMPTION AND USES

The manufacture of heavy clay products including (1) building brick, sewer pipe and drain, roofing, structural, terra cotta, and other tile; (2) portland cement clinker; and (3) lightweight aggregate accounted for 35%, 20%, and 10%, respectively, of total domestic consumption. In summary, 65% of all clay produced was consumed in the manufacture of these clay- and shale-based construction materials.

**Heavy Clay Products.**—The value reported for shipments by the Bureau of the Census of heavy clay products increased 6% to about $1.43 billion. The million standard brick count for building or common face brick increased slightly. Shipments of clay floor and wall tile increased 9%, while vitrified clay sewer pipe and fittings decreased 7%. Increases in common clay and shale used in building brick manufacturing occurred in most States with total domestic production increasing 3%. Increases were largely under 10% with an average State upturn of about 6%.

**Lightweight Aggregates.**—Consumption of clay and shale in the manufacture of lightweight aggregate increased nearly 8% to about 4.7 million tons. The upturn in overall construction uses, except for the largest category, concrete block (55% of total production), which declined 2%, was largely responsible. Highway surfacing increased 22%, while the second largest consuming area, structural concrete (30% of production), increased 18%. The new market areas, such as recreational and horticultural uses included in the other category, increased 24%.

**Refractories.**—All types of clay were used in manufacturing refractories. Bentonite, fire clay, and kaolin accounted for 28%, 32%, and 19%, respectively, of total clay used for this purpose. The remainder, ball clay, common clay and shale, and fuller's earth, were used chiefly as bonding agents. Bentonite, both swelling and nonswelling, was used as a bonding agent in proprietary foundry formulations imparting both green strength and hot strength to the sand.

## Table 20.—Clays sold or used by producers in the United States[1] in 1985, by use

(Short tons)

| Use | Ball clay | Bentonite | Common clay and shale | Fire clay (refractory only) | Fuller's earth | Kaolin | Total |
|---|---|---|---|---|---|---|---|
| Absorbents: | | | | | | | |
| Oil and grease absorbents | -- | 34,493 | W | -- | 600,627 | -- | 635,120 |
| Pet waste absorbents | -- | W | W | 29,200 | 781,669 | -- | 810,869 |
| Other[2] | -- | 61,494 | 135,349 | -- | -- | -- | 196,843 |
| Ceramics and glass: | | | | | | | |
| Catalysts (oil-refining) | W | 8,218 | -- | -- | W | 219,934 | 228,152 |
| Crockery and other earthenware | W | -- | 8,331 | 16,134 | -- | W | 24,465 |
| Electrical porcelain | 42,240 | -- | 54 | -- | -- | 25,122 | 67,416 |
| Fine china and dinnerware | 27,491 | -- | -- | -- | -- | 16,090 | 43,581 |
| Glasses, glass, enamels | 1,606 | W | -- | 5,000 | W | 489 | 7,095 |
| Mineral wool and insulation, fiberglass | W | W | -- | -- | -- | 303,551 | 303,551 |
| Pottery | 208,498 | -- | 9,361 | 2,023 | W | 15,431 | 230,308 |
| Roofing granules | -- | 1,029 | 100,600 | -- | -- | 23,779 | 125,408 |
| Sanitary ware | 153,097 | -- | -- | -- | W | 137,178 | 290,275 |
| Other[2] | 108,014 | 2,507 | -- | -- | 6,270 | -- | 116,791 |
| Chemical manufacturing | -- | 2,986 | -- | -- | 1,772 | 46,461 | 51,219 |
| Civil engineering and sealing | -- | 123,308 | 148,710 | -- | -- | 4,866 | 276,884 |
| Drilling mud | W | 1,186,641 | -- | -- | 106,980 | 104 | 1,293,725 |
| Fillers, extenders, binders: | | | | | | | |
| Adhesives | W | 8,938 | -- | W | 2,740 | 97,573 | 109,251 |
| Animal feed | 13,943 | 130,484 | 4,090 | W | -- | 11,107 | 159,584 |
| Fertilizers | -- | -- | -- | -- | 57,381 | 29,102 | 86,483 |
| Gypsum products and wallboard | -- | -- | -- | -- | W | 8,417 | 8,417 |
| Ink | -- | W | -- | -- | -- | W | W |
| Medical, pharmaceutical, cosmetic | W | 3,968 | -- | -- | 94 | 3,804 | 7,866 |
| Paint | W | 7,161 | 50 | -- | 10,395 | 199,680 | 217,286 |
| Paper coating | W | W | -- | -- | -- | 2,266,846 | 2,266,846 |
| Paper filling | W | W | -- | -- | 2,759 | 1,173,178 | 1,175,937 |
| Pesticides and related products | W | 1,182 | 5,144 | -- | 256,812 | 67,229 | 330,317 |
| Plastics | -- | W | -- | W | W | 54,118 | 54,118 |
| Rubber | W | W | 7,410 | W | -- | 313,991 | 321,401 |
| Other[2] | 16,699 | 7,533 | -- | 1,500 | 3,120 | 942 | 29,794 |
| Filtering, clarifying, decolorizing: | | | | | | | |
| Animal oils | -- | 1,741 | -- | -- | -- | 650 | 2,391 |
| Desiccants | -- | 29,200 | -- | -- | -- | -- | 29,200 |
| Mineral oils and greases | -- | 8,630 | -- | -- | 15,321 | -- | 23,951 |

See footnotes at end of table.

## Table 20.—Clays sold or used by producers in the United States[1] in 1985, by use —Continued

(Short tons)

| Use | Ball clay | Bentonite | Common clay and shale | Fire clay (refractory only) | Fuller's earth | Kaolin | Total |
|---|---|---|---|---|---|---|---|
| Floor and wall tile: | | | | | | | |
| Ceramic | 129,052 | -- | 97,746 | 12,759 | -- | 18,082 | 257,639 |
| Quarry tile | -- | -- | 189,146 | -- | -- | -- | 189,146 |
| Other | 6,316 | -- | -- | -- | -- | 57,676 | 63,992 |
| Heavy clay products: | | | | | | | |
| Brick, common | 2,921 | 3,433 | 2,522,955 | 176 | -- | 10,840 | 2,540,325 |
| Brick, face | -- | -- | 12,450,809 | 16,861 | -- | 483,546 | 12,951,216 |
| Drain tile | -- | -- | 30,624 | -- | -- | -- | 30,624 |
| Flower pots | -- | -- | 42,401 | -- | -- | -- | 42,401 |
| Flue linings | -- | -- | 64,890 | 9,983 | -- | 3,064 | 77,937 |
| Portland and other cements | -- | 611 | 8,708,502 | 3,405 | -- | 135,117 | 8,847,635 |
| Roofing tile | -- | -- | 23,574 | -- | -- | -- | 23,574 |
| Sewer pipe, vitrified | -- | -- | 282,068 | 223 | -- | 8,768 | 291,059 |
| Structural tile | -- | -- | 36,975 | -- | -- | 371 | 37,346 |
| Terra cotta | -- | -- | 887 | -- | -- | -- | 887 |
| Other | -- | 16,584 | 6,024 | -- | -- | -- | 22,608 |
| Lightweight aggregate: | | | | | | | |
| Concrete block | -- | -- | 2,612,678 | -- | -- | -- | 2,612,678 |
| Highway surfacing | -- | -- | 546,382 | -- | -- | -- | 546,382 |
| Structural concrete | -- | -- | 1,412,858 | -- | -- | 502 | 1,413,360 |
| Other | -- | -- | 138,898 | -- | -- | -- | 138,898 |
| Pelletizing iron ore | -- | 290,567 | -- | -- | -- | -- | 290,567 |
| Refractories: | | | | | | | |
| Firebrick, blocks and shapes | W | 1,542 | 135,454 | 491,290 | -- | 6,653 | 634,939 |
| Foundry sand | -- | 728,587 | -- | 69,477 | -- | 964 | 799,028 |
| Grogs and calcines | W | -- | -- | 137,438 | -- | 290,824 | 428,262 |
| High alumina brick and specialties | 6,627 | 6,714 | -- | 66,712 | -- | 111,934 | 191,987 |
| Kiln furniture | 1,708 | -- | -- | -- | -- | 1,747 | 3,455 |
| Mortar and cement, refractory | W | -- | 289,376 | 90,532 | 26,198 | 92,785 | 498,891 |
| Other[2] | 110,659 | -- | -- | -- | -- | -- | 110,659 |
| Other[3] | -- | 101,203 | 133,552 | 15,647 | 43,423 | 249,289 | 543,114 |
| Exports | 77,813 | 426,576 | 23,517 | 6,054 | 143,720 | 1,301,523 | 1,979,203 |
| Total | 901,679 | 8,195,280 | 30,168,325 | 974,414 | 2,059,281 | 7,793,322 | 45,092,301 |

W Withheld to avoid disclosing company proprietary data; included with "Total" and/or "Other."

[1] Includes Puerto Rico.

[2] Includes uses indicated by symbol W.

[3] Includes tamping dummies and uses not specified.

## Table 21.—Shipments of principal structural clay products in the United States

| Product | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Unglazed common and face brick: | | | | | |
| Quantity ........ million standard brick | 5,202 | 4,407 | 5,792 | 6,510 | 6,605 |
| Value ........ million | $540 | $504 | $704 | $836 | $887 |
| Unglazed structural tile: | | | | | |
| Quantity ........ million standard brick | 92 | 49 | 30 | 32 | 55 |
| Value ........ million | $8 | $6 | $5 | $7 | $12 |
| Vitrified clay and sewer pipe fittings: | | | | | |
| Quantity ........ million standard brick | 463 | 325 | 375 | 397 | 368 |
| Value ........ million | $73 | $52 | $64 | $79 | $78 |
| Unglazed, salt-glazed, ceramic-glazed structural facing tile including glazed brick: | | | | | |
| Quantity ........ million standard brick | 35 | 11 | W | W | W |
| Value ........ million | $10 | $8 | W | W | W |
| Clay floor and wall tile including quarry tile: | | | | | |
| Quantity ........ million standard brick | 288 | 296 | 333 | 340 | 370 |
| Value ........ million | $341 | $354 | $388 | $421 | $450 |
| Total value[1] ........ do | $972 | $923 | $1,161 | $1,342 | $1,428 |

W Withheld to avoid disclosing company proprietary data.

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census Report Form M32-D (84), Current Industrial Reports—Clay Construction Products.

## Table 22.—Common clay and shale used in building brick production in the United States, by State

| State | 1984 | | 1985 | |
|---|---|---|---|---|
| | Short tons | Value | Short tons | Value |
| Alabama | 721,338 | $2,924,014 | 784,324 | $3,585,969 |
| Arizona and New Mexico | 143,866 | 380,227 | 137,851 | 390,099 |
| Arkansas | 498,325 | 1,269,049 | 518,199 | 1,337,518 |
| California | 378,644 | 1,527,701 | 379,976 | 2,099,790 |
| Colorado | 291,547 | 1,937,112 | 280,611 | 1,572,065 |
| Connecticut and New Jersey | 149,078 | 1,314,620 | 226,083 | 2,431,878 |
| Georgia | 1,356,003 | 3,782,607 | 1,458,993 | 4,429,269 |
| Illinois | 106,740 | 402,342 | 116,840 | 462,611 |
| Indiana and Iowa | 361,865 | 926,670 | 315,833 | 829,789 |
| Kansas | 193,022 | 585,701 | 173,832 | 459,968 |
| Kentucky | 292,800 | 1,354,941 | 285,266 | 1,299,938 |
| Louisiana | 117,404 | 306,673 | 111,237 | 273,845 |
| Maine, Massachusetts, New Hampshire | 166,451 | 860,538 | 193,572 | 1,014,908 |
| Maryland and West Virginia | 375,013 | 1,515,289 | 376,537 | 1,714,440 |
| Michigan and Minnesota | 51,641 | 123,111 | 54,771 | 168,528 |
| Mississippi | r919,621 | r5,155,238 | 751,920 | 2,980,254 |
| Missouri | 84,373 | 358,183 | 74,025 | 291,796 |
| Nebraska and North Dakota | 180,927 | 490,011 | 183,586 | 439,974 |
| New York | 88,397 | 90,248 | 134,551 | 186,451 |
| North Carolina | 2,067,546 | 7,398,557 | 2,250,402 | 7,625,482 |
| Ohio | 919,971 | 3,205,889 | 972,163 | 3,423,479 |
| Oklahoma | 518,107 | 1,661,852 | 543,985 | 1,491,028 |
| Oregon | 18,874 | 41,001 | 17,848 | 37,838 |
| Pennsylvania | 765,237 | 2,857,355 | 782,491 | 3,020,028 |
| South Carolina | 660,974 | 2,540,845 | 688,556 | 1,523,674 |
| Tennessee | 394,182 | 685,569 | 416,599 | 788,947 |
| Texas | 1,725,337 | 7,331,347 | 1,705,625 | 8,450,887 |
| Utah | 217,914 | 1,645,138 | 191,430 | 1,402,828 |
| Virginia | 583,405 | 1,634,348 | 680,724 | 1,948,756 |
| Washington | 150,115 | 415,315 | 130,117 | 351,137 |
| Wyoming | 44,711 | 558,079 | 35,917 | 466,562 |
| Total | r14,538,428 | r55,229,570 | 14,973,764 | 56,439,651 |

r Revised.

The tonnage of clays used for refractories decreased slightly and constituted 6% of total clay produced. An increase in the use of high-alumina clay-based refractories, in particular, calcined kaolin grogs, in monoliths offset the decline in production of the more conventional refractory bricks and shapes. The major refractory consuming industries—cement, foundry, glass, ferrous and nonferrous metals—continued to undergo major changes in technology and production levels for their products. Metal imports further exacerbated the industry's problems.

**Filler.**—All kinds of clay have been used to some extent as fillers in one or more areas of use. Bentonite, fuller's earth, and kaolin are the principal filler clays. Kaolin, either air-floated, water-washed, low-temperature calcined, and/or delaminated, is used in the manufacture of paper, rubber, paint, and plastics. Fuller's earth is used primarily in pesticides and fertilizers. Clays are in pesticides and fertilizers as either thickeners, carriers, diluents, or prilling agents. Bentonites were used mainly in animal feeds.

Of the total clay produced, 11% was used in filler applications; of this, kaolin accounted for 89%; fuller's earth, 7%; bentonite, 3%; and ball clay, common clay and shale, and fire clay, the remaining 1%. Kaolin consumed as fillers decreased slightly to 4.2 million tons. An approximate 8% decline in paper coater-grade kaolin, which constitutes 54% of the total filler and extender category, was largely responsible. Increases occurred in most of the other filler categories for kaolin, except for paint and plastics, which decreased 13% and 8%, respectively. The paper filling and pesticides end uses increased 19% and 59%, respectively, while the other increases were more modest, generally under 6%. The total quantity of fuller's earth used in pesticides and related products, such as fungicides, increased nearly 19% over that of 1984.

**Absorbent Uses.**—Absorbent uses for clays accounted for over 1.6 million tons, or about 4% of total clay consumption. Demand for absorbents increased 8%. Fuller's earth was the principal clay used for absorbent purposes, and this application accounted for 84% of its entire output. Demand for clays in pet waste absorbents, representing nearly 49% of absorbent use, decreased 15%. Use in floor absorbents, chiefly to absorb hazardous oily substances, accounted for another 39% of the absorbent demand, which rose 14% above that of 1984. An upturn in the industrial sector, large consumers of floor absorbents, and the economy in general were responsible for the increased consumption.

**Drilling Mud.**—Demand for clays in rotary-drilling muds decreased 12% to about 1.3 million tons and accounted for nearly 3% of total clay production. This decrease reestablished the downward trend, except for the increase noted in 1984, begun in 1982 when a combination of excess oil production and economic uncertainties resulted in lower oil and gas well-drilling activities, which depressed bentonite demand. Oil and gas well-drilling activity softened further at yearend because of additional overproduction. Swelling-type bentonite remained the principal clay used in drilling-mud mixes, although fuller's earth, used mostly in saltwater drilling techniques, and nonswelling sodium-activated bentonites, were also used to a limited extent. Bentonite and fuller's earth accounted for nearly 100% of the total amount of clay used in this category. Small amounts of ball clay and kaolin were used in specialized formulations.

**Floor and Wall Tile.**—Common clay and shale, ball clay, kaolin, and fire clay, in order of volume, were used in manufacturing floor, wall, and quarry tile. This end-use category accounted for about 1% of the total clay production. Downsizing of homes, in part due to the need for remaining competitive in the marketplace, has largely ended with declining interest rates.

**Pelletizing Iron Ore.**—Bentonite continued to be used as a binder in forming indurated iron ore pellets. Demand decreased nearly 28% to about 291,000 tons. Inroads of inexpensive Mediterranean area bentonite, largely sodium-activated, into the traditional U.S. clay marketing area of the Great Lakes, coupled with lower demand due to changing technology, metal imports, and shrinking production levels, have all combined to lessen the demand for domestic bentonites in this category.

**Ceramics.**—Total demand for clay in the manufacture of pottery, sanitary ware, fine china and dinnerware, and related products (excluding clay flower pots) accounted for 3% of the total clay output. This demand, principally ball and kaolin clays, increased slightly to nearly 1.44 million tons. The increase in this category was also attributed to the increased demand for residential housing because of declining interest rates.

**Table 23.—Common clay and shale used in lightweight aggregate production in the United States, by State**

| State | Short tons | | | | | Total value |
|---|---|---|---|---|---|---|
| | Concrete block | Structural concrete | Highway surfacing | Other | Total | |
| **1984** | | | | | | |
| Alabama and Arkansas | 521,001 | 146,007 | 19,364 | 4,200 | 690,572 | $3,698,200 |
| California | 123,481 | 201,091 | -- | 19,114 | 343,686 | 2,788,638 |
| Florida, Indiana, Iowa | 185,874 | 39,600 | 26,122 | -- | 251,596 | 698,494 |
| Kansas, Kentucky, Louisiana | 538,537 | 192,028 | 48,707 | 12,347 | 791,619 | 13,830,093 |
| Massachusetts, Mississippi, Missouri | 256,722 | 80,096 | 23,715 | -- | 360,533 | 1,846,549 |
| Montana and New York | 148,050 | 137,750 | -- | -- | 285,800 | 2,000,500 |
| North Carolina and North Dakota | 124,120 | 81,642 | -- | 24 | 205,786 | 572,927 |
| Ohio, Oklahoma, Pennsylvania | 227,232 | 35,733 | 100 | -- | 263,065 | 577,377 |
| Utah and Virginia | 144,215 | 32,509 | -- | 8,036 | 184,760 | 2,276,592 |
| Texas | 401,978 | 247,789 | 329,766 | 20,988 | 1,000,521 | 4,997,293 |
| **Total** | **2,671,210** | **1,194,245** | **447,774** | **64,709** | **4,377,938** | **33,286,663** |
| **1985** | | | | | | |
| Alabama and Arkansas | 708,200 | 190,857 | 14,683 | -- | 913,740 | 4,321,766 |
| California | 131,897 | 237,737 | -- | 15,049 | 384,683 | 3,364,460 |
| Florida and Indiana | 192,210 | 43,200 | 13,000 | -- | 248,410 | 689,528 |
| Kansas, Kentucky, Louisiana | 412,713 | 124,844 | 25,250 | 8,126 | 570,933 | 9,916,737 |
| Massachusetts, Mississippi, Missouri | 221,385 | 75,156 | 36,461 | -- | 333,002 | 1,779,111 |
| Montana and New York | 208,650 | 178,250 | -- | -- | 386,900 | 2,455,240 |
| North Carolina | 210,000 | 140,000 | -- | -- | 350,000 | 881,000 |
| Ohio, Oklahoma, Pennsylvania | 186,536 | 45,448 | 1,460 | -- | 233,444 | 640,219 |
| Utah and Virginia | 146,772 | 32,249 | 5,707 | 1,040 | 185,768 | 2,395,170 |
| Texas | 194,315 | 345,117 | 449,821 | 114,683 | 1,103,936 | 2,355,859 |
| Total | 2,612,678 | 1,412,858 | 546,382 | 138,898 | 4,710,816 | 28,799,090 |

## Table 24.—Shipments of refractories in the United States, by product

| Product | Unit of quantity | 1984 |  | 1985 |  |
|---|---|---|---|---|---|
|  |  | Quantity | Value (thousands) | Quantity | Value (thousands) |
| CLAY REFRACTORIES |  |  |  |  |  |
| Superduty fire clay brick and shapes | 1,000 9-inch equivalent. | 34,422 | $41,887 | 26,509 | $33,517 |
| Other fire clay including semisilica brick and shapes, glasshouse pots, tank blocks, feeder parts, upper structure parts used only for glass tanks. | do | 66,368 | 44,742 | 65,969 | 50,272 |
| High-alumina (50% to 60% $Al_2O_3$) brick and shapes made of calcined diaspore or bauxite.[1] | do | 81,957 | 151,578 | 71,271 | 138,314 |
| Insulating firebrick and shapes | do | 29,296 | 29,677 | 16,577 | 16,429 |
| Ladle brick | do | 36,763 | 22,622 | 45,261 | 28,778 |
| Sleeves, nozzles, runner brick, tuyeres | do | 20,665 | 30,475 | 31,965 | 27,996 |
| Hot-top refractories | Short tons | W | W | W | W |
| Kiln furniture, radiant heater elements, potter's supplies, other miscellaneous-shaped refractory items. | do | 28,769 | 26,526 | XX | 25,333 |
| Refractory bonding mortars | do | 30,317 | 36,589 | XX | 40,478 |
| Plastic refractories and ramming mixes, containing up to 87.5% $Al_2O_3$.[2] | do | 96,968 | 48,362 | XX | 43,346 |
| Castable refractories | do | 219,939 | 88,687 | XX | 87,434 |
| Gunning mixes | do | 85,551 | 31,121 | XX | 33,450 |
| Other clay refractory materials sold in lump or ground form.[3] [4] | do | 505,525 | 230,092 | XX | 104,391 |
| Total clay refractories |  | XX | 782,308 | XX | 629,738 |
| NONCLAY REFRACTORIES |  |  |  |  |  |
| Silica brick and shapes | 1,000 9-inch equivalent. | 7,095 | 15,025 | 5,728 | 13,608 |
| Magnesite and magnesite-chrome brick and shapes. | do | 25,754 | 112,129 | 24,512 | 113,426 |
| Chrome and chrome-magnesite brick and shapes. | do | 38,656 | 154,045 | 30,822 | 125,325 |
| Shaped refractories containing natural graphite. | Short tons | 17,461 | 33,308 | 12,924 | 30,552 |
| Zircon and zirconia brick and shapes; other carbon refractories: Forsterite, pyrophyllite, dolomite, dolomite-magnesite molten-cast,[5] other brick and shapes. | 1,000 9-inch equivalent. | 5,043 | 36,762 | 1,084 | 37,269 |
| Other mullite, kyanite, sillimanite, or andalusite brick and shapes. | do | 3,734 | 16,100 | 3,506 | 18,319 |
| Other extra-high (over 50%) alumina brick and fused bauxite, fused alumina, dense-sintered alumina shapes.[6] | do | 3,677 | 46,611 | 64,425 | 48,113 |
| Silicon carbide brick, shapes, kiln furniture | do | 1,674 | 34,845 | 1,284 | 33,834 |
| Refractory bonding mortars | Short tons | 14,223 | 9,792 | XX | 11,942 |
| Hydraulic-setting nonclay refractory castables | do | 23,742 | 23,978 | 21,130 | 20,363 |
| Plastic refractories and ramming mixes | do | 130,966 | 87,041 | XX | 79,740 |
| Gunning mixes | do | 233,381 | 36,709 | XX | 109,130 |
| Dead-burned magnesia or magnesite[3] [7] | do | 376,029 | 102,160 | XX | 141,836 |
| Dead-burned dolomite | do | 309,291 | 18,002 | XX | 23,111 |
| Other nonclay refractory material sold in lump or ground form.[3] | do | 218,433 | 47,834 | XX | 63,169 |
| Total nonclay refractories |  | XX | 824,336 | XX | 874,727 |
| Grand total refractories |  | XX | 1,606,644 | XX | 1,504,465 |

W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1] Heat short of fusion; volatile materials are thus driven off in the presence of chemical changes, giving more stable material for refractory use.

[2] More or less plastic brick and materials that, after the addition of any water needed, are rammed into place.

[3] Materials for domestic use as finished refractories and all exported material.

[4] Includes calcined clay, ground brick, and siliceous and other gunning mixes.

[5] Molten cast refractories are made by fusing refractory oxides and pouring the molten material into molds to form finished shapes.

[6] Completely melted and cooled, then crushed and graded for use in a refractory.

[7] Includes shipments to refractory producers for reprocessing in the manufacture of other refractories.

Source: Bureau of the Census Report Form MQ32-C (84), Current Industrial Reports—Refractory.

## Table 25.—U.S. exports of clays in 1985, by country

(Thousand short tons and thousand dollars)

| Country | Ball clay |  | Bentonite |  | Fire clay |  | Fuller's earth |  | Kaolin |  | Clays, n.e.c. |  | Total |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| Argentina | -- | -- | (1) | 46 | -- | -- | (1) | 11 | 12 | 2,092 | 1 | 884 | 13 | 2,986 |
| Australia | (1) | 3 | 21 | 1,179 | 15 | 1,055 | (1) | 4 | 12 | 2,166 | 2 | 1,110 | 50 | 5,517 |
| Belgium-Luxembourg | (1) | 9 | (1) | 43 | 53 | 3,956 | 2 | 373 | 14 | 1,907 | 1 | 257 | 70 | 6,545 |
| Brazil | (1) | 12 | 12 | 2,071 | -- | -- | (1) | 10 | 3 | 873 | 15 | 12,599 | 30 | 15,565 |
| Canada | 33 | 1,329 | 312 | 16,280 | 28 | 1,856 | 76 | 5,722 | 277 | 26,544 | 24 | 2,554 | 750 | 54,285 |
| Chile | (1) | 33 | 1 | 182 | -- | -- | (1) | 3 | 2 | 801 | (1) | 64 | 3 | 1,083 |
| Colombia | -- | -- | 14 | 774 | (1) | 19 | (1) | 5 | 8 | 1,183 | 5 | 4,427 | 27 | 6,408 |
| Ecuador | 3 | 237 | 1 | 136 | (1) | 10 | 1 | 232 | 3 | 177 | 1 | 163 | 9 | 955 |
| Finland | (1) | 11 | -- | -- | -- | -- | -- | -- | 10 | 1,747 | (1) | 8 | 10 | 1,766 |
| France | (1) | 17 | 1 | 111 | 1 | 154 | (1) | 96 | 13 | 2,650 | 1 | 539 | 16 | 3,567 |
| Germany, Federal Republic of | 41 | 142 | 16 | 873 | (1) | 59 | (1) | 30 | 41 | 4,166 | 3 | 1,336 | 101 | 6,606 |
| Hong Kong | -- | -- | 1 | 210 | -- | -- | -- | -- | 1 | 132 | (1) | 58 | 2 | 400 |
| Italy | -- | -- | (1) | 70 | 4 | 356 | 2 | 222 | 107 | 11,912 | (1) | 65 | 113 | 12,625 |
| Japan | (1) | 187 | 94 | 8,826 | 61 | 5,245 | (1) | 76 | 437 | 60,169 | 88 | 13,777 | 680 | 88,280 |
| Korea, Republic of | (1) | 10 | 4 | 991 | -- | -- | -- | -- | 47 | 9,278 | 3 | 495 | 54 | 10,774 |
| Mexico | 123 | 4,310 | 2 | 311 | 25 | 1,732 | (1) | 2 | 93 | 9,248 | 27 | 6,540 | 270 | 22,143 |
| Netherlands | -- | -- | 24 | 1,645 | (1) | 54 | 18 | 1,412 | 156 | 14,634 | 27 | 2,377 | 225 | 20,122 |
| Peru | -- | -- | 1 | 159 | -- | -- | -- | -- | 2 | 439 | 1 | 859 | 4 | 1,457 |
| Philippines | 2 | 171 | 3 | 389 | -- | -- | (1) | 82 | 2 | 474 | 2 | 291 | 9 | 1,407 |
| Saudi Arabia | -- | -- | 7 | 307 | -- | -- | (1) | 10 | (1) | 19 | (1) | 64 | 7 | 400 |
| Singapore | (1) | 41 | 26 | 1,683 | -- | -- | (1) | 52 | 2 | 461 | (1) | 208 | 28 | 2,445 |
| South Africa, Republic of | (1) | 8 | (1) | 65 | -- | -- | 1 | 186 | 5 | 1,081 | (1) | 168 | 6 | 1,508 |
| Spain | -- | -- | (1) | 185 | (1) | 19 | -- | -- | 13 | 2,138 | (1) | 221 | 13 | 2,513 |
| Sweden | (1) | 10 | (1) | 7 | 10 | 1,012 | (1) | 9 | 19 | 2,043 | 8 | 1,143 | 37 | 4,224 |
| Switzerland | (1) | 11 | (1) | 3 | 12 | 829 | (1) | 2 | 1 | 212 | (1) | 4 | 13 | 1,061 |
| Taiwan | (1) | 27 | 17 | 1,788 | 5 | 340 | (1) | 2 | 46 | 5,969 | (1) | 121 | 68 | 8,247 |
| Thailand | (1) | 4 | 5 | 550 | -- | -- | -- | -- | 3 | 584 | 1 | 187 | 9 | 1,325 |
| United Arab Emirates | -- | -- | 3 | 258 | (1) | 4 | (1) | 46 | -- | -- | (1) | 117 | 3 | 425 |
| United Kingdom | 1 | 33 | 20 | 1,129 | 7 | 941 | 3 | 385 | 6 | 2,295 | 7 | 3,735 | 44 | 8,518 |
| Venezuela | (1) | 40 | 10 | 886 | (1) | 12 | (1) | 22 | 15 | 2,439 | 4 | 616 | 29 | 4,015 |
| Other | 1 | 130 | 45 | 3,816 | 1 | 156 | 1 | 191 | 31 | 6,351 | 7 | 2,044 | 86 | 12,688 |
| Total[2] | 204 | 6,775 | 640 | 44,973 | 228 | 17,809 | 104 | 9,185 | 1,381 | 174,204 | 228 | 56,975 | 2,780 | 309,871 |

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

Source: U.S. Department of Commerce.

## Table 26.—U.S. imports for consumption of clays in 1985, by kind

| Kind | Quantity (short tons) | Value (thousands) |
|---|---|---|
| China clay or kaolin: | | |
| Canada | 75 | $12 |
| Germany, Federal Republic of | 2 | 5 |
| Netherlands | 18 | 20 |
| Taiwan | 3 | 2 |
| United Kingdom | 9,288 | 956 |
| Total[1] | 9,387 | 996 |
| Fuller's earth, not beneficiated: | | |
| Belgium | 24 | 4 |
| Canada | 44 | 2 |
| France | 7 | 2 |
| Jamaica | 25 | 2 |
| Senegal | 3,638 | 133 |
| Total | 3,738 | 143 |
| Fuller's earth, beneficiated: | | |
| Guinea | 20 | 3 |
| United Kingdom | 56 | 7 |
| Total | 76 | 10 |
| Bentonite: | | |
| Canada | 1,044 | 197 |
| China | 30 | 14 |
| Denmark | 2 | 4 |
| Japan | 2 | 5 |
| Mexico | 5,805 | 85 |
| Norway | 47 | 4 |
| Singapore | 958 | 143 |
| United Kingdom | 215 | 59 |
| Total[1] | 8,104 | 511 |
| Common blue and other ball clay, not beneficiated: United Kingdom | 92 | 11 |
| Common blue and other ball clay, wholly or partly beneficiated: | | |
| Netherlands | 22 | 3 |
| United Kingdom | 1,155 | 134 |
| Total | 1,177 | 137 |
| Other clay, not beneficiated: | | |
| Canada | 28 | 4 |
| Japan | 22 | 6 |
| United Kingdom | 1,704 | 19 |
| Total | 1,754 | 29 |
| Clay, n.e.c., beneficiated: | | |
| Belgium | 4 | 5 |
| Brazil | 28 | 13 |
| Canada | 327 | 94 |
| Denmark | 1 | 3 |
| France | 103 | 27 |
| Germany, Federal Republic of | 211 | 40 |
| Italy | 10 | 1 |
| Japan | 1 | 2 |
| Netherlands | 1 | 1 |
| United Kingdom | 1,445 | 294 |
| Total | 2,131 | 480 |
| Artificially activated clay: | | |
| Canada | 3,151 | 858 |
| Germany, Federal Republic of | 180 | 133 |
| Japan | 13 | 20 |
| Mexico | 10,700 | 2,512 |
| Switzerland | 20 | 39 |
| United Kingdom | 379 | 102 |
| Total | 14,443 | 3,664 |
| Grand total | 40,902 | 5,981 |

[1] Data may not add to totals shown because of independent rounding.

Source: U.S. Department of Commerce.

## WORLD REVIEW

Estimated world production of all grades of fuller's earth increased almost 7%, kaolin increased slightly, while bentonite decreased nearly 4%. World fuller's earth production during the year was about 2.7 million tons, and U.S. output accounted for 76% of the total. Bentonite production was 6.2 million tons, with the United States accounting for 51% of the total. Kaolin production was nearly 23.4 million tons, and U.S. output was 33% of the world total.

**Australia.**—Kaiser, Oakland, CA, was planning to sell most of its clay and nonclay refractory assets in Australia to Morganite Australia Pty. Ltd., a subsidiary of Morgan Crucible Co. PLC, London, United Kingdom, for an undisclosed sum. Kaiser (see "Fire Clay" section) was negotiating with an employee group for a leveraged buyout of its North American refractories division as part of its intent to withdraw from the refractories business.

**Barbados.**—American investors purchased the assets of the country's only brick manufacturer, Building Supplies Ltd., which included a factory near its clay deposits in the St. Andrew area. The investors intended to convert the facility into a clay floor and wall tile manufacturing plant, destined largely for export to the Florida and Texas markets. The U.S. group was striving to take advantage of the duty-free provisions of the Caribbean Basin Initiative (CBI) that eliminates import duties for most Caribbean products through 1995. Clay brick tile exports from non-CBI countries pay a 23% import duty in the United States. Future plans included a high-tech ceramic line for the U.S. automotive industry.

**Brazil.**—Caolim da Amazonas announced a 100% expansion of its 250,000-ton-per-year paper-grade kaolin plant on the Rio Jari, with construction scheduled for mid-1986.[3]

**Canada.**—Oil-Dri Corp. of America, a Chicago-based absorbent clay company, purchased the remaining 50% of Favorite Products Co. of Montreal.[4] Favorite is the leading Canadian marketer of absorbent clays. Assets include a modern automated packaging plant and production facilities for manufacturing Oil-Dri's proprietary absorbents. The new management plans to expand Favorite's markets into the Maritime Provinces and Ontario and provide research and development support.

The Calgary-based Ekaton Energy Ltd. established a wholly owned subsidiary, Ancon Research and Engineering Ltd., to provide technical expertise on developing the parent company's kaolinized sand property in the Wood Mountain and Eastend acres in Saskatchewan.[5] The company's plans called for constructing a wet beneficiating plant to separate the kaolin and sand fractions in 1987 after an initial development program. The kaolin was targeted for the domestic paper filler market, and the sand, for local amber glass production. Carlson Mines Ltd. has obtained an option to buy up to a 50% interest in a kaolin sand deposit northwest of Smooth Rock Falls in Ontario.[6] Carlson planned to develop the deposits, which contain proven reserves of over 50 million tons of kaolin and silica sand.

Jannock Ltd. purchased the operations of Domtar Inc.'s brickworks in Ottawa and Mississauga in Ontario and one in La Prairie, Quebec, capable of producing 130 million bricks annually.[7]

**Chile.**—The Government planned to entertain bids for developing the Solar de Uyuni salt deposits.[8] The concession area, located about 250 miles from La Paz in the Department of Potosí, in addition to salt, lithium, potassium, and boron values, also contains large reserves of kaolin.

**China.**—A bentonite deposit, reportedly China's largest, with verified reserves near 70 million tons, was found near Changchun in Jilin.[9] The deposit, situated under a coal seam, reportedly averages 300 feet in thickness, and at the present rate of coal production, upwards of 200 tons per day of bentonite could be extracted. A deposit of over 2 billion tons of a unique illite clay was discovered in Ji County, Tianjin Municipality.[10] The county plans to become a major producer, along with Yixing Town in Jiangsu Province, for the distinctive purple sand pottery.

**Finland.**—A large kaolin deposit, containing about 20 million tons of ore, was found by the Geological Research Center and Lohja Oy in Paljakka, close to Puolanka in the north.[11] Feasibility studies were under way to optimize a mining and processing scheme to yield paper quality clays. Finland's paper industry imports nearly 400,000 tons of English china clay yearly.

**Germany, Federal Republic of.**—The manufacturing operations of Oil-Dri, a Chicago-based U.S. firm, were acquired by Laporte Industries Ltd. of the United Kingdom for about $4 million.[12] The acquisition not only included Oil-Dri's Cologne plant, which manufactures granular absorbent clay products for agricultural, industrial, and pet waste uses, but also its European marketing operations in Switzerland. The acquisition agreement provided for Oil-Dri to supply Laporte with Georgia fuller's earth clays for further processing. In addition, the two companies planned to cooperate in their European business and in technology transfer. This latest acquisition in the Federal Republic of Germany and another in the Netherlands appear to fit in with Laporte's efforts to make inroads into European bentonite and/or fuller's earth markets.

Eduard Kick GmbH, the country's second largest producer, installed and commissioned a new 84-inch high-intensity wet magnetic PEM separator at its Schnaittenbach plant.[13] Kick processes the sand kaolins of the Hirschau-Schnaittenbach Basin for the local paper, ceramics, and fiberglass industries.

**Greece.**—A new $1 million bentonite processing plant was under development by Silver and Baryte Ores Mining Co. to increase its processing capacity for granulating, sodium activating, and drying clays on the Island of Milos to nearly 500,000 tons per year.[14] The company's bentonite sales were chiefly for iron ore pellets (70%), foundries (20%), and oil and/or gas drilling (10%). Large deposits of high-quality clays were situated in the Laconia and Arcadia Provinces in Peloponnesia.[15] The clays were reported to be suitable for manufacturing high-quality ceramics and were the first deposits to be found that are in economically exploitable quantities.

**India.**—The nation's first ceramic floor tile plant was established in Andhra Pradesh in a joint venture with an unnamed U.S. company. The fully automated plant's output, capable of expanding to 25,000 tons per year, was targeted for the growing West Asian and Far Eastern export markets. The Geological Survey of India's recent publication, in its exploratory survey of the State of Orissa, listed reserves of fire clay and kaolin to be 150 million and 100 million tons, respectively.[16]

**Netherlands.**—Holland Laporte, a member of the Laporte Industries Group, acquired Dayton BV, an independent chemicals marketing and trading company.[17] Dayton has been active in marketing a significant portion of Laporte's bentonite products in Western Europe. This latest acquisition by Laporte followed its pattern of increasing its presence in European and Asian markets.

**Pakistan.**—The Government ordered further exploration and trenching to determine the bentonite reserves of the deposits in the hilly areas of Dera Ghazi Kahn to eliminate Pakistan's dependence on imports.[18] In other Government action, fire clay reserves of nearly 60 million tons were discovered in the mountainous region of the Kala Chitta District of Attock.[19] The Government claimed that this recent fire clay find would permit the country to be self-sufficient in refractory- and ceramic-grade clays for the foreseeable future. Large deposits of china clay have been located in the Tharparkar District by the Pakistan Mineral Development Corp. (PMDC).[20] Identified reserves were estimated to be about 4 million tons, but the new deposit is in difficult terrain. Nevertheless, PMDC developed a mining and clay washing procedure, which it forwarded to Government officials for evaluation.

**Philippines.**—A local company, Naga Hardwood Ltd., planned on developing its kaolin and industrial sand deposit with a joint venture partner experienced in sand kaolin technology and processing.[21]

**Qatar.**—A geological survey for industrial minerals carried out by the Industrial Development Technical Centre of Qatar located promising deposits of several different unspecified clay types.[22]

**Senegal.**—Société Sénégalaise des Phosphates de Thiès (SSPT), co-owned by the Government and Rhône-Poulenc S.A. of France, planned to treble its attapulgite production capacity at its Lam Lam Mine and mill complex in the Thiès District from 110,000 to 330,000 tons per year.[23] The clay is used principally by the West European domestic and industrial absorbent markets, the major outlet being for a pet waste absorbent line.

**Spain.**—The Government approved Laporte's (United Kingdom) plans to complete the acquisition of Minas de Gador S.A.[24] Minas de Gador mines bentonite in the Almería region in the south and bentonite and sepiolite in the Yuncos area, about 25 miles south of Madrid. The company produces a complete line of bentonites for use in foundries, drilling mud, animal feed, and bleaching earths for oil refining. In addition, sepiolite from Yuncos is also used in saltwater drilling muds and industrial and pet waste absorbents. Minas de Gador, which markets heavily in the European and African Mediterranean countries, was reportedly planning, under Laporte's direction, to increase its production capacity for specialty activated clays. In a related event, Laporte and Sociedad Tolsa S.A. agreed to exchange certain clay business sectors.[25] The agreement permits each company, Laporte through its newly acquired subsidiary, Minas de Gador, and Tolsa, to further specialize within their own areas of expertise. Tolsa is to specialize in the production of sepiolite, and Minas de Gador, in the production of bleaching earths (attapulgite and/or fuller's earth) and bentonite. This agreement freed additional production capacity at existing plants by ending competitive products.

Tolsa's Toledo plant planned to produce special rheological sepiolite grades to meet the shortfall, if it should materialize, for Tolsa's Madrid plant, which produces approximately 500,000 tons per year of absorbent-grade sepiolite granules. Tolsa continued to produce sepiolite in the Madrid-Toledo area at Vicalvaro-Yunclillos while the other Tolsa Group companies, Hifran S.A. and Minas de Torrejon S.A., continued to produce a sepiolitic marl at Lebriva in Seville and attapulgite at Torrejon el Rubio in Cáceres, respectively. Laporte's Minas de Gador became the sole Spanish bleaching earth producer. Its Yuncos plant capacity was increased an additional 30,000 tons per year.

A new 60,000-ton-per-year processing plant for the production of paper coater- and filler-grade kaolins from a kaolinitic sand, at Poveda de la Sierra in the Guadalajara Province about 100 miles northeast of Madrid, went on-stream.[26] The plant is owned by Cía. Española de Caolines S.A., a joint venture between English China Clays PLC (ECC) of the United Kingdom, Caobar S.A., and a private interest. The kaolin deposit is said to contain roughly 20 years' reserves of clays of sufficient brightness so as not to require the costly conventional bleaching and magnetic separation processing steps.

**Turkey.**—The State mining company Etibank evaluated proposals from foreign mining companies for jointly developing selected bentonite properties.[27]

**U.S.S.R.**—The bentonite mines and processing plants at Sarigyukh near Idzhevan in Armenia were reportedly the largest in the Soviet Union.[28] Their 1.3-million-ton-per-year output supposedly represents one-third of the total Soviet production.

**United Kingdom.**—ECC, the world's largest kaolin producer, increased its holdings in Watts Blake Bearne & Co. PLC (WBB), the world's largest ball clay producer, to nearly 21% of its outstanding shares.[29] WBB and ECC produce both kaolin and ball clay and are major factors in the domestic and international clay markets. ECC has reaffirmed its promise not to sit on WBB's board. An agreement was announced by Hepworth Ceramic Holdings PLC and British Steel Corp. (BSC) on merging their subsidiaries, G. R. Stein Refractories Ltd. and BSC Refractories Group, respectively, into G. R. Stein.[30] As a result of the merger, Hepworth held 78% and BSC held 22% of the enlarged company, which strived to combine manufacturing facilities and develop the latest refractories technology. The consequent rationalization of operating capacity, from 11 to 7 refractory, research, and development laboratories, and manufacturing facilities did not affect the Manual Works, which produced clay and/or alumina-silicate refractories, including bricks, shapes, and monolithics.

The Yorkshire Brick Co.'s Stairfoot, Barnsley, plant fired its natural gas tunnel kilns with inexpensive methane gas recovered and piped from the company's nearby quarries.[31] The quarries were once repositories for residential refuse. The plant's capacity was doubled to 20 million bricks per year to take advantage of the unexpected windfall.

**Yugoslavia.**—Reserves of high-quality ceramic-grade clay, estimated at 20 million tons, have been found near Arandjelovac in Serbia.[32] The deposit was reportedly the nation's richest, and plans were under way to develop a 70,000-ton-per-year mining operation.

**Zambia.**—The Development Bank of Zambia and others financed a ceramic whiteware factory in Kitwe scheduled to use indigenous clays.[33] The new plant, equipped with state-of-the-art West German and British manufacturing machinery, will produce sanitary ware, tiles, and tableware for local consumption.

## Table 27.—Kaolin: World production, by country[1]

(Thousand short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria[e] | 21 | 17 | 19 | [3]9 | 9 |
| Argentina | 74 | 80 | 160 | 100 | 110 |
| Australia | 188 | 168 | 127 | [e]275 | 140 |
| Austria (marketable) | 87 | 85 | 92 | 110 | 95 |
| Bangladesh[4] | 11 | 6 | 8 | 8 | [3]5 |
| Belgium | 60 | 58 | 66 | 76 | 76 |
| Brazil (beneficiated) | 518 | 544 | 463 | 536 | 550 |
| Bulgaria | 244 | 261 | 267 | 282 | 285 |
| Burundi | [e]2 | [e]2 | 4 | 2 | [3]5 |
| Chile | 63 | 23 | 45 | 54 | [3]54 |
| Colombia | 898 | 943 | 840 | 1,034 | 990 |
| Costa Rica | 1 | 1 | [e]1 | [e]1 | 1 |
| Czechoslovakia | 560 | 581 | 730 | 736 | 720 |
| Denmark[e] | [r]11 | [3]6 | [r]11 | [r]15 | 17 |
| Ecuador | 8 | 5 | 1 | [e]1 | 2 |
| Egypt | 85 | 55 | 110 | [r] [e]130 | 130 |
| Ethiopia (including Eritrea) | 10 | [e]10 | [e]10 | ([5]) | NA |
| France[6] | 865 | [r]383 | 819 | 838 | 840 |
| German Democratic Republic (marketable)[e] | 220 | 230 | 220 | 190 | 190 |
| Germany, Federal Republic of (marketable) | 523 | 500 | 448 | 452 | 465 |
| Greece | [r]35 | 49 | 67 | 101 | 80 |
| Hong Kong | 9 | ([7]) | 1 | ([7]) | 10 |
| Hungary | 58 | 50 | 41 | 43 | [3]32 |
| India: | | | | | |
| Salable, crude | 482 | 585 | 610 | 555 | 570 |
| Processed | 126 | [e]110 | [e]110 | 128 | 120 |
| Indonesia | 89 | 85 | 66 | 92 | 90 |
| Iran[e] | 110 | 121 | 110 | 110 | 110 |
| Israel | 41 | 18 | 30 | [e]30 | 30 |
| Italy: | | | | | |
| Crude | 82 | 59 | 58 | 58 | [3]66 |
| Kaolinitic earth | 34 | 32 | 28 | 28 | [3]29 |
| Japan | 232 | 218 | 254 | 248 | [3]245 |
| Kenya | [e]2 | 1 | 1 | ([7]) | ([7]) |
| Korea, Republic of | 766 | 690 | 754 | 795 | 725 |
| Madagascar | 2 | 3 | [e]3 | [e]3 | 3 |
| Malaysia | 49 | 49 | 63 | 80 | 90 |
| Mexico | 229 | 190 | 179 | 144 | 165 |
| Mozambique | ([7]) | ([7]) | ([7]) | ([7]) | ([7]) |
| New Zealand | 54 | 26 | 26 | 28 | 275 |
| Nigeria | 1 | [e]1 | [e]1 | ([7]) | ([7]) |
| Pakistan | [r]45 | [r]49 | 14 | 20 | 5 |
| Paraguay | 77 | 61 | 50 | 55 | 55 |
| Peru[e] | 7 | 7 | 7 | 7 | 7 |
| Poland | [r]48 | 51 | 54 | [e]55 | 56 |
| Portugal | 58 | 56 | 63 | 96 | [3]102 |
| Romania[e] | 452 | 452 | 452 | 452 | 452 |
| South Africa, Republic of | 165 | 141 | 143 | 150 | [3]142 |
| Spain (marketable)[8] | 872 | 763 | 782 | 921 | 940 |
| Sri Lanka | 8 | 9 | 9 | 12 | 11 |
| Sweden | ([7]) | ([7]) | ([7]) | [e]([7]) | ([7]) |
| Taiwan | 100 | 96 | 118 | 88 | 85 |
| Tanzania | [e]1 | [e]1 | 1 | 2 | 2 |
| Thailand | 16 | 20 | 40 | 65 | 60 |
| Turkey | 49 | [e]50 | [e]60 | 61 | 60 |
| U.S.S.R.[e] | 2,800 | 2,900 | 2,900 | 3,100 | 3,200 |
| United Kingdom | [r]2,897 | [r]2,669 | 3,000 | 3,274 | 3,300 |
| United States[9] | 7,660 | 6,862 | 7,203 | 7,953 | [3]7,793 |
| Venezuela | 72 | [e]72 | 12 | 24 | 25 |
| Vietnam[e] | 1 | 1 | 1 | 1 | 1 |
| Yugoslavia | 248 | [r]261 | 230 | [r] [e]230 | 240 |
| Zimbabwe | 5 | 3 | 1 | 1 | 1 |
| Total | [r]21,821 | [r]20,264 | 21,473 | 23,354 | 23,361 |

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[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1]Table includes data available through July 15, 1986.

[2]In addition to the countries listed, China, Lebanon, and Suriname also produced kaolin, but information is inadequate to make reliable estimates of output levels. Guatemala and Morocco each produced less than 500 tons in each of the years covered by this table.

[3]Reported figure.

[4]Data for year ending June 30 of that stated.

[5]Revised to not available.

[6]Includes kaolinitic clay.

[7]Less than 1/2 unit.

[8]Includes crude and washed kaolin and refractory clays not further described.

[9]Kaolin sold or used by producers.

## Table 28.—Bentonite: World production, by country[1]

(Short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria[e] [3] | 38,600 | 38,600 | 33,100 | [4]27,000 | 27,600 |
| Argentina | 135,274 | 135,864 | 149,439 | 89,876 | 99,000 |
| Australia[3] | 18,635 | 32,201 | 33,098 | [r] [e]33,000 | 33,000 |
| Brazil | 183,356 | 180,845 | 141,857 | 221,592 | 220,000 |
| Burma | 2,554 | 1,613 | 895 | 799 | [4]783 |
| Cyprus[5] | 51,809 | 14,330 | 35,300 | 35,715 | [4]57,300 |
| Egypt[e] | 5,700 | 5,700 | 2,800 | 3,300 | 3,300 |
| France | [e]3,307 | 3,627 | 3,407 | 3,831 | 3,500 |
| Greece | 343,862 | 343,921 | 759,427 | 857,600 | 827,000 |
| Guatemala[e] | 2,750 | [4]2,750 | 8,800 | [r]9,400 | 9,400 |
| Hungary | 88,770 | 93,624 | 87,972 | 70,722 | [4]65,966 |
| Iran[e] | 11,000 | 12,100 | 11,000 | 11,000 | 11,000 |
| Israel (metabentonite) | 13,868 | 13,228 | 7,538 | 6,501 | 13,200 |
| Italy | 305,340 | [r]261,200 | 327,183 | 340,600 | [4]329,600 |
| Japan | 564,141 | 533,993 | 486,034 | 452,034 | [4]508,749 |
| Mexico | 243,009 | 203,837 | 249,276 | 294,700 | 280,000 |
| Morocco | 3,203 | 4,913 | 4,515 | 2,012 | 2,200 |
| Mozambique | 789 | 1,604 | 276 | 446 | 440 |
| New Zealand (processed) | 2,078 | 6,856 | 2,158 | 7,075 | 2,200 |
| Pakistan | [r]1,155 | [r]1,572 | 735 | 1,918 | 1,800 |
| Peru[e] | [4]33,620 | 34,200 | 34,200 | 35,300 | 35,300 |
| Philippines | 6,092 | 5,149 | 739 | 41,715 | 1,800 |
| Poland[e] | 55,000 | 77,000 | 77,000 | 77,000 | 83,000 |
| Romania[e] | 194,000 | [r]193,000 | [r]195,000 | 198,000 | 198,000 |
| South Africa, Republic of | 48,912 | 33,981 | 43,573 | 46,131 | [4]47,910 |
| Spain | [r]121,250 | [r]123,800 | 90,976 | 80,008 | 80,000 |
| Tanzania | 55 | 55 | [e]83 | [e]83 | 83 |
| Turkey | 33,827 | [e]34,200 | [e]34,200 | 30,967 | 31,000 |
| United States | 4,947,000 | 3,244,800 | 2,886,870 | 3,437,940 | [4]3,195,280 |
| Zimbabwe | 86,424 | 94,236 | 69,552 | [r] [e]77,000 | 77,000 |
| Total | [r]7,545,380 | [r]5,732,799 | 5,777,003 | 6,493,265 | 6,245,411 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through July 15, 1986.

[2] In addition to the countries listed, Canada, China, the Federal Republic of Germany, the U.S.S.R., and Yugoslavia are believed to produce bentonite, but output is not reported, and available information is inadequate to make reliable estimates of output levels.

[3] Includes bentonitic clays.

[4] Reported figure.

[5] Includes bleaching earths.

## Table 29.—Fuller's earth: World production, by country[1]

(Short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria[e] | [r]5,600 | [r]5,600 | [r]5,500 | [3]3,858 | 3,900 |
| Argentina | 5,783 | 13,002 | 7,431 | 3,980 | 5,500 |
| Australia (attapulgite) | -- | 16,280 | [e]16,500 | [e]16,500 | 16,500 |
| Italy[e] | [3]6,057 | 6,000 | 5,500 | 5,500 | 5,500 |
| Mexico | 72,067 | 46,835 | 45,827 | 50,372 | 50,000 |
| Morocco (smectite) | 21,771 | 27,121 | 30,187 | 36,824 | 37,000 |
| Pakistan | [r]19,369 | [r]15,205 | 23,298 | 21,097 | 19,000 |
| Senegal (attapulgite) | [r]36,346 | 109,128 | 110,644 | 127,315 | 128,000 |
| South Africa, Republic of | 478 | 343 | 344 | -- | -- |
| Spain (attapulgite) | 52,059 | 47,318 | 49,228 | 48,399 | 49,000 |
| United Kingdom | [r]208,927 | [r]206,132 | 211,644 | 315,261 | 330,000 |
| United States[4] | 1,655,854 | 1,682,655 | 1,911,634 | 1,899,145 | [3]2,059,281 |
| Total | [r]2,079,311 | [r]2,175,619 | 2,417,732 | 2,528,251 | 2,703,681 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Excludes centrally planned economy countries, some of which presumably produce fuller's earth, but for which no information is available. Table includes data available through July 15, 1986.

[2] In addition to the market economy countries listed, France, Iran, Japan, and Turkey have reportedly produced fuller's earth in the past and may continue to do so, but output is not reported, and available information is inadequate to make reliable estimates of output levels.

[3] Reported figure.

[4] Sold or used by producers.

## TECHNOLOGY

The Bureau of Mines published the results of research on the pressure leaching of alumina from a typical dried air-floated and raw Georgia kaolin with hydrochloric acid (HCl).[34] The optimized pressure leaching step with excess 20-weight-percent HCl at temperatures that ranged from 150° C to 225° C successfully extracted greater than 90% alumina when digestion periods were 2 hours or less. These data indicate a choice in optimizing a flowheet for alumina from kaolin between a faster reaction at 200° C or a slower reaction at a lower pressure at 175° C.

An article described the working plan, clay extraction and preparation, and the chamotte[35] burning process.[36] The work highlighted the equipment, specifications, chemistry, and flowsheets used in the manufacturing process for chamottes. The solid-state transformation of refractory-grade kaolins or chamottes into mullitic grogs was studied extensively by nuclear magnetic resonance.[37] The kaolin was shown to decompose sequentially to a metakaolinite with expulsion of excess silica into a high-temperature crystalline form upon cooling. The metakaolinite was successfully indexed as a gamma-alumina structure formed simply by removal of hydroxyl ions from the kaolin structure by a diffusion controlled mechanism. The mullites, which are end products of these solid-state reactions, are widely used in refractory bricks and specialty products. The results of this basic research should allow refractories manufacturers to better control the physical properties of the mullite component to optimize the density of these high-performance refractories.

The relationship between pore structure and building brick durability was investigated.[38] The research showed that bricks of poor durability had a preponderance of pores smaller than 1 micrometer, while acceptable brick exhibited a majority of its pores larger than 2 micrometers. The results indicated that controlling raw material composition and forming methods were the key to superior brick production. Grog and shales larger than 200 mesh were recommended over pure clay, and soft-molding brick processes, over extrusion techniques. In addition, poor brick durability was successfully correlated with low porosity surfaces and/or high porosity interiors. This work should permit the brick industry to more readily predict the durability of material without resorting to the more cumbersome and tedious testing procedures presently used. The primary types of clay refractories, fire clay, semisilica, high-alumina, insulating and ladle bricks, and monolithic shapes used by the metal casting industry were the topic of a review article.[39] A feature of the article included definitions and specifications for each type of refractory commonly used and correlates its foundry applications with selected physical and chemical properties. Future refractory trends in metal casting processes, prompted by technological changes, were also discussed in detail.

The relationship of geologic setting and kaolin characteristics to filler applications were the topics of a technical oral presentation.[40] The paper pointed out the differences between the kaolins of the Georgia-South Carolina Clay Belt and correlated them with selected filler applications. A brief description of the general schemes for kaolin beneficiation in the Clay Belt were also outlined. The air-float and water-washed beneficiation processes along with individual details of the classification, leaching, filtration, drying, and slurry preparation steps were singled out for more elaborate treatment. Of particular interest was the correlation between the processing scheme practiced and the physical and chemical properties of the clay types encountered.

A comprehensive technical work was published on the acid-activated montmorillonite, hectorite, organoclay, saponite, white bentonite, sepiolite, attapulgite, and halloysite clays.[41] The work consisted of a series of articles on each of these individual clay types or products falling into the all-encompassing bentonite and fuller's earth categories. A special feature of each of the segments was the worldwide treatment afforded each clay as to individual companies and the major markets served. Another highlight of the report was the chemistry of the acid-activated and organoclay processes, the gelling mechanism, and the overall theory of organoclays.

A paper on the mineral requirements of the paint manufacturers in the United States, Western Europe, and Japan for increasing specialized grade materials was published.[42] The article also discusses the physiochemistry of the three main paint components: pigment, medium (binder or vehicle), and solvent (thinner). Special tables listing typical analyses for paint-grade kaolins as well as the current British standard specifications for china clay extenders in paint were also included. An interesting feature of the article was the wide range of substitutability possible in pigment material, chiefly to reduce raw material cost yet still capable of producing a high-quality competitive paint. A similar treatment was afforded the English cosmetics industry.[43] A highlight of this work was the technical specifications for face powder kaolins and special clays used for their absorbing, degreasing, thixotropic, and pigment suspending properties.

An indepth review was published of major industrial minerals, including bentonite, kaolin, plastic, and fire clays currently mined and processed in the Federal Republic of Germany.[44] The review covered the geology, mineralogy, output, production flowsheets, and consumption of clays by the domestic refractory, ceramics, glass, and paper industries. A special feature of the article was a table on major areas of application for crude, acid, alkaline, and organically activated bentonites. A similar detailed treatment, but more heavily oriented toward a geological, mining, and mineralogical approach, was afforded sepiolite, attapulgite, bentonite, and to a lesser degree, kaolin, produced in Spain.[45] Tables highlighting the physical and chemical properties of foundry and gelling bentonite and ceramic grades were also listed.

The geological and production aspects of the industrial minerals exploited in California,[46] Greece,[47] and Jamaica[48] were discussed briefly in other publications. The California paper stressed the mining and production flowsheets for the Ione kaolin, and the Greek work targeted bentonite and kaolin production. A highlight of the latter paper was an industrial minerals map of Greece depicting the major bentonite and kaolin production sites, largely on the islands of Lesvos and Milos. The Jamaican article, strictly an overview, dealt with its 16 major clay deposits, mostly bentonite, kaolin, and common clays, currently under investigation for ceramic and structural product manufacturing.

A concise but detailed study was published on the Chinese bentonite industry.[49] The article provides the latest information on Chinese bentonite resources, exploration, mining, processing, physical and chemical properties, research, and marketing goals. The Chinese bentonites are widely distributed, and China is regarded as being second only to the United States as a worldwide source of bentonites. Chinese specifications with typical analyses for sodium-exchanged, organoclad drilling-mud and foundry and iron ore grades of bentonite were listed and discussed. A case study of the Heishen open pit and Linan underground mines was included.

The differences in thermal decomposition of sodium and calcium bentonites and their role in foundry sand bonding during metal casting was explored in detail.[50] The data showed that bentonite burnout and consumption depend on many factors, but the sand-to-metal ratio, cooling time, and time of casting in the mold emerge as the most important. U.S. sodium and calcium bentonites were used throughout the investigation as the reference base and/or standard material. The technical rationale for the past, present, and future industrial minerals usage by the U.S. drilling industry was published.[51] The paper stressed the indispensability of bentonite gelling clays and new material usages, such as organoclays, in oil-based drilling fluids.

The preferential absorption of selected environmental toxins, such as dioxin, by modified smectites or bentonites was researched.[52] The investigation showed that smectites bound to hydroxy aluminum are three times more effective than activated carbon, at present the most commonly used industrial sorbent, in removing toxins from industrial effluents. Future work should lead to additional modified clay systems capable of removing other chemical pollutions and toxins. Clays have the advantage of being a relatively inexpensive commodity compared with other industrial and reagent chemicals, such as activated carbon and zeolites.

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[1] Physical scientist, Division of Industrial Minerals.

[2] Albany slip clay is included with ball clay solely for statistical convenience.

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[8] Industrial Minerals (London). Company News and Mineral Notes. No. 211, Apr. 1985, p. 95.

[9] ———. Company News and Mineral Notes. No. 218, Nov. 1985, p. 81.

[10] Work cited in footnote 9.

[11] U.S. Embassy, Helsinki. State Dep. Airgram A-02, 2 pp.

[12] Industrial Minerals (London). World of Minerals: Europe—Laporte Expands Further in Europe. No. 215, Aug. 1985, p. 11.

[13] Work cited in footnote 8.

[14] Industrial Minerals (London). World of Minerals: Greece—Silver and Baryte Bentonite Development. No. 215, Aug. 1985, p. 12.

[15] ———. Company News and Mineral Notes. No. 214, July 1985, p. 76.

[16] Page 94 of work cited in footnote 8.

[17] Work cited in footnote 12.

[18] Industrial Minerals (London). Company News and Mineral Notes. No. 212, May 1985, p. 67.

[19] ———. Company News and Mineral Notes. No. 209, Feb. 1985, p. 67.

[20] ———. Company News and Mineral Notes. No. 216, Sept. 1985, p. 109.

[21] Work cited in footnote 8.

[22] Work cited in footnote 18.

[23] Industrial Minerals (London). World of Minerals: Senegal Attapulgite Output To Treble. No. 206, Nov. 1984, pp. 14-15.

[24] ———. World of Minerals: Spain—Laporte To Control Minas de Gador. No. 213, June 1985, p. 11.

[25] ———. World of Minerals: Spain—Laporte and Tolsa Exchange Clays. No. 215, Aug. 1985, p. 13.

[26] ———. Spain: Paper Coating Clay Plant Officially Opened. No. 215, Aug. 1985, pp. 13-14.

[27] ———. Company News and Mineral Notes. No. 215, Aug. 1985, p. 64.

[28] Soviet Geography. New Railroad Opens in Transcaucasia. V. 27, No. 3, Mar. 1986, pp. 202-203.

[29] Industrial Minerals (London). World of Minerals: United Kingdom—ECC Ups WBB's Stake by 2%. No. 216, Sept. 1985, pp. 17-18.

[30] ———. U.K.—G. R. Stein Merges With BSC. No. 213, June 1985, pp. 11-14.

[31] Brick and Clay Record. Industry Newsfront: Yorkshire Brick Fires Kiln With Methane Gas. V. 187, No. 3, Sept. 1985, p. 11.

[32] Page 66 of work cited in footnote 19.

[33] Work cited in footnote 16.

[34] Sawyer, D. L., Jr., and T. L. Turner. Pressure Leaching Alumina From Raw Kaolinitic Clay Using Hydrochloric Acid. BuMines RI 8978, 1985, 18 pp.

[35] Calcined kaolin and/or bauxite mixtures also referred to as grogs and calcines for refractories.

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# Cobalt

## By William S. Kirk[1]

Domestic cobalt consumption decreased after 2 consecutive years of increases. Apparent consumption dropped to 15.7 million pounds. A realignment of the international cobalt market occurred during 1985, precipitated when a Canadian cobalt producer concluded a contract for the purchase of feedstock that had formerly been refined in the United States. This action resulted in the closure of the sole domestic cobalt refinery. The spot price for electrolytic cobalt fell slightly, ending the year at $11.10 per pound. There was no domestic mine production of cobalt.

**Domestic Data Coverage.**—Domestic consumption data for cobalt are developed by the Bureau of Mines from two voluntary surveys of U.S. operations. Of the 695 operations to which a survey request was sent, 551 responded, representing 97% of the reported consumption shown in tables 1, 3, and 4. The remainder was estimated by contacting industry sources.

**Table 1.—Salient cobalt statistics**

(Thousand pounds of contained cobalt unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Consumption, reported | 11,680 | 9,468 | 11,319 | 12,944 | 13,541 |
| Imports for consumption | 15,594 | 12,870 | 17,221 | 25,310 | 17,708 |
| Stocks, Dec. 31: | | | | | |
| Consumer | 1,411 | 1,327 | 1,441 | 1,368 | 1,131 |
| Processor | 1,519 | 1,161 | 1,366 | 1,781 | 1,557 |
| Price: Metal, per pound | $17.26-$25.00 | [1]$8.56 | [1]$5.76 | [1]$10.40 | [1]$11.43 |
| World: Production[2] | 67,790 | [r]54,062 | 52,292 | [p]71,738 | [e]79,734 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Based on weighted average of Metals Week prices.

[2]Based on estimated recovered cobalt.

**Legislation and Government Programs.**—In an effort to develop emergency response plans to avert accidents, such as the catastrophic leak in Bhopal, India, the Environmental Protection Agency compiled a list of 402 acutely toxic substances.[2] The list contained an extensive compilation of the substances' properties and health effects. Cobalt and cobalt carbonyl were included among the substances listed.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, cobalt would be categorized in tier I with a goal of 22.57 million pounds of cobalt and in tier II with a goal of 6 million pounds of cobalt. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

Cobalt-rich manganese crusts on Pacific sea mounts were not likely to be developed in the near future, according to the Office of Strategic and International Minerals, Minerals Management Service (MMS), U.S. Department of the Interior. The MMS announced that an Environmental Impact Statement (EIS) would be prepared for a proposed lease sale of the crusts within the Hawaiian Exclusive Economic Zone. After hearings and preparation of the final EIS, the Secretary of the Interior was to decide whether to proceed with a lease sale, which was scheduled to take place in middle to late 1987. Following the lease sale, detailed exploration was to take at least 5 years, and the construction of mining equipment and onshore facilities, another 5 or 10 years.

## DOMESTIC PRODUCTION

The sole domestic cobalt refinery, at Braithwaite, LA, closed late in 1985 because it lost its source of raw material. AMAX Nickel Inc., owner and operator of the refinery, terminated the supply contract for the nickel-copper-cobalt matte, which had been produced in Botswana. The matte had accounted for about two-thirds of the refinery's feedstock, the remainder having come from the Agnew Mine in Australia, owned jointly by Seltrust Holdings Ltd. and Mount Isa Mines Ltd. AMAX Nickel was reported to be hoping for an expansion of production capacity at the Agnew Mine or an arrangement to have the Agnew matte toll refined. According to reports, however, the Agnew Mine was unable to increase its capacity owing to ground control problems, and AMAX Nickel was unable to interest other refiners in a toll-refining agreement. With insufficient raw material to support economical operations, AMAX Nickel was forced to close the refinery and withdraw from the cobalt market.

Following the completion of a feasibility study, Hall Chemical Co., Wickliffe, OH, awarded a preliminary engineering contract for its catalyst reclamation project. The project was expected to result in the construction of a plant, located in the gulf coast region, to be operational in late 1988. The facility was to process spent catalysts and have the capacity to recycle 650,000 pounds of cobalt per year to be used in the chemical industry.

**Table 2.—U.S. cobalt products[1] produced and shipped by refiners and processors**

(Thousand pounds)

| | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Production | | Shipments | | Production | | Shipments | |
| | Gross weight | Cobalt content | Gross weight | Cobalt content | Gross weight | Cobalt content | Gross weight | Cobalt content |
| Driers (organic compounds) | NA | 1,329 | NA | 1,300 | NA | 1,188 | NA | 1,190 |
| Hydrate (hydroxide) | NA | 1,228 | NA | 1,219 | NA | 1,149 | NA | 1,014 |
| Salts[2] (inorganic compounds) | NA | 942 | NA | 803 | NA | 539 | NA | 612 |
| Total | NA | 3,449 | NA | 3,322 | NA | 2,876 | NA | 2,816 |

NA Not available.

[1] Figures on oxide withheld to avoid disclosing company proprietary data.

[2] Various salts combined to avoid disclosing company proprietary data.

## CONSUMPTION AND USES

Cobalt consumption decreased after 2 consecutive years of increases. Although reported consumption was 13.5 million pounds in 1985, compared with 12.9 million pounds in 1984, the increase was due to improved statistical coverage. Apparent consumption, calculated from net imports, secondary production, and changes in industry and Government stocks, decreased to 15.7 million pounds, 12% less than that of 1984. The decline in consumption was due to weakened demand and inventory adjustments. In the last half of the year, consumers became aware that prices were declining and would continue to do so. They therefore began reducing their inventory levels.

Of the 6.4 million pounds of cobalt reported to have been consumed in the production of superalloys during the year, approximately 500,000 pounds was used in the production of prosthetic devices (surgical implants), according to industry sources. In general, alloys used in prosthetic devices and superalloys were produced in the same facilities.

### Table 3.—U.S. consumption of cobalt, by end use

(Thousand pounds of contained cobalt)

| End use | 1984 | 1985 |
|---|---|---|
| Steel: | | |
| Full-alloy | W | W |
| High-strength, low-alloy | W | W |
| Stainless and heat-resisting | 74 | 61 |
| Tool | 353 | 203 |
| Superalloys | 4,766 | 6,380 |
| Alloys (excludes alloy steels and superalloys): | | |
| Cutting and wear-resistant materials[1] | 831 | 1,017 |
| Magnetic alloys | 2,209 | 1,455 |
| Nonferrous alloys | 176 | [2]W |
| Welding materials (structural and hard-facing) | 399 | W |
| Other alloys | 15 | [2]122 |
| Mill products made from metal powder | W | W |
| Chemical and ceramic uses: | | |
| Catalysts | 1,296 | 1,253 |
| Drier in paints or related usage | 1,258 | 1,139 |
| Feed or nutritive additive | 58 | 46 |
| Glass decolorizer | 41 | 42 |
| Ground coat frit | 617 | 724 |
| Pigments | 417 | 401 |
| Miscellaneous and unspecified | 434 | 698 |
| Total | 12,944 | 13,541 |

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

[1] Cemented and sintered carbides and cast carbide dies or parts.

[2] Data not comparable to 1984 data because of change in end-use definitions.

### Table 4.—U.S. consumption of cobalt, by form

(Thousand pounds of contained cobalt)

| Form | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Chemical compounds (organic and inorganic) other than oxide | 2,421 | 1,643 | 2,297 | 2,226 | 1,850 |
| Metal | 7,450 | 6,055 | 7,165 | 8,746 | 9,463 |
| Oxide | 557 | 732 | 938 | 915 | 1,201 |
| Purchased scrap | 972 | 871 | 723 | 879 | 897 |
| Other | 280 | 167 | 196 | 178 | 130 |
| Total | 11,680 | 9,468 | 11,319 | 12,944 | 13,541 |

## PRICES

The listed producer price for cobalt cathodes remained at $12.50 per pound, unchanged since 1982, but was no longer the price standard. The spot price for cathodes began the year at $11.50 per pound, reached $11.60 at midyear, and then experienced a slight and gradual deterioration, ending the year at $11.10. The decline occurred despite the efforts of Zaire to maintain an unofficial producer price of $11.70 per pound.

## Table 5.—Yearend published prices of cobalt materials[1]

(Dollars per pound)

| Material | 1983 | 1984 | 1985 |
|---|---|---|---|
| Cobalt:[2] | | | |
| Fine powder | 10.11 | [r]16.63 | 19.05 |
| Powder | 6.91 | 13.24 | 14.87 |
| Cobalt oxide: | | | |
| Ceramic-grade (70% cobalt) | 4.90 | 9.40 | 9.98 |
| Ceramic-grade (72% cobalt) | 5.04 | 9.66 | 10.26 |
| Metallurgical-grade (76% cobalt) | 5.21 | 9.86 | 10.61 |

[r] Revised.
[1] Metals Week.
[2] See table 1 for cathode price.

## FOREIGN TRADE

Exports of unwrought cobalt metal and waste and scrap totaled 911,000 pounds, gross weight, with an estimated 643,000 pounds cobalt content, valued at $7.3 million. These exports were shipped to 35 countries, with the following, in descending order, receiving the largest quantities: Belgium, Japan, the Federal Republic of Germany, and the United Kingdom. Exports of wrought metal totaled 487,000 pounds, gross weight, valued at $8.2 million. Of the 20 countries to which cobalt was shipped, the major recipients, in descending order, were France, Canada, Japan, and the United Kingdom.

Imports of cobalt metal originating in south-central Africa, that is, imports from Belgium-Luxembourg (Zairian origin), Zaire, and Zambia, represented 56% of total cobalt imports compared with 71% from that area in 1984.

## Table 6.—U.S. imports for consumption of cobalt, by class

(Thousand pounds and thousand dollars)

| Class | 1983 | 1984 | 1985 |
|---|---|---|---|
| Metal:[1] | | | |
| Gross weight | 15,853 | 23,316 | 16,613 |
| Cobalt content[e] | 15,853 | 23,316 | 16,613 |
| Value | $110,076 | $202,954 | $181,379 |
| Oxide: | | | |
| Gross weight | 403 | 706 | 246 |
| Cobalt content[e] | 298 | 522 | 182 |
| Value | $1,813 | $5,285 | $2,258 |
| Salts and compounds: | | | |
| Gross weight | 1,671 | 2,284 | 1,413 |
| Cobalt content[e] | 502 | 685 | 424 |
| Value | $2,244 | $5,371 | $4,431 |
| Other forms:[2] | 568 | 787 | 489 |
| Value | $1,969 | $4,793 | $3,356 |
| Total content | 17,221 | 25,310 | 17,708 |

[e] Estimated.
[1] Includes unwrought metal and waste and scrap.
[2] Contained cobalt in nickel-copper and nickel matte.

Source: Bureau of the Census.

## Table 7.—U.S. imports for consumption of cobalt, by country

(Thousand pounds and thousand dollars)

| Country | Metal[1] | | | | Oxide[2] | | | | Other forms[3] | | | | Total content[4,5] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1984 | | 1985 | | 1984 | | 1985 | | 1984 | | 1985 | | | |
| | Gross weight | Value | Gross weight | Value | Gross weight | Value | Gross weight | Value | Cobalt content | Value | Cobalt content | Value | 1984 | 1985 |
| Australia | 15 | 82 | 6 | 26 | (6) | (6) | -- | -- | 218 | [7]1,341 | 82 | [7]559 | 233 | 87 |
| Belgium-Luxembourg | 903 | 9,137 | 845 | 9,975 | 466 | 3,578 | 162 | 1,423 | 201 | 2,405 | 62 | 908 | 1,449 | 1,026 |
| Botswana | -- | -- | -- | -- | -- | -- | -- | -- | 569 | [7]3,452 | 296 | [7]2,027 | 569 | 296 |
| Canada | 3,044 | 29,016 | 3,047 | 33,568 | 71 | 481 | 36 | 317 | 32 | 175 | 32 | 212 | 3,128 | 3,105 |
| Finland | 958 | 9,498 | 984 | 11,712 | -- | -- | 5 | 126 | -- | -- | 10 | 270 | 958 | 994 |
| France | 298 | 1,332 | 62 | 543 | 2 | 40 | -- | -- | 1 | 15 | (6) | 13 | 301 | 66 |
| Germany, Federal Republic of | 69 | 821 | 109 | 1,280 | 47 | 344 | -- | -- | 68 | 496 | 22 | 252 | 171 | 131 |
| Japan | 224 | 1,134 | 132 | 912 | -- | -- | -- | -- | 14 | 128 | 17 | 423 | 238 | 149 |
| Netherlands | 202 | 2,294 | 300 | 3,738 | -- | -- | -- | -- | 2 | 57 | -- | -- | 204 | 300 |
| Norway | 1,382 | 6,312 | 1,693 | 18,601 | -- | -- | -- | -- | -- | -- | -- | -- | 1,382 | 1,693 |
| South Africa, Republic of | 39 | 288 | 14 | 151 | -- | -- | 1 | 5 | 285 | 1,395 | 275 | [7]2,038 | 324 | 290 |
| United Kingdom | 439 | 2,948 | 192 | 1,443 | 74 | 565 | 42 | 387 | 68 | 547 | 75 | 942 | 563 | 298 |
| Zaire | 11,728 | 108,172 | 4,801 | 59,056 | 45 | 276 | -- | -- | 11 | 139 | -- | -- | 11,772 | 4,801 |
| Zambia | 3,796 | 29,662 | 4,318 | 39,958 | -- | -- | -- | -- | -- | -- | -- | -- | 3,796 | 4,318 |
| Zimbabwe | -- | -- | (6) | 1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | (6) |
| Other | 219 | 2,259 | 110 | 414 | -- | -- | -- | -- | 3 | 13 | 44 | 144 | 222 | 154 |
| **Total[5]** | **23,316** | **202,954** | **16,613** | **181,379** | **706** | **5,285** | **246** | **2,258** | **1,472** | **10,163** | **918** | **7,788** | **25,310** | **17,708** |

[1] Includes unwrought metal and waste and scrap.

[2] Gross weight figures for cobalt oxide do not indicate cobalt content.

[3] Contained cobalt in nickel-copper and nickel matte from Australia and Botswana. Salts and compounds were imported from the remaining countries.

[4] Estimated content cobalt.

[5] Data may not add to totals shown because of independent rounding.

[6] Less than 1/2 unit.

[7] Based on weighted average cobalt metal price of $10.40 per pound for 1984 and $11.43 per pound for 1985, multiplied by 0.6 (estimated factor for matte) for imports from Australia, Botswana, and the Republic of South Africa.

Source: Bureau of the Census.

Table 8.—U.S. import duties for cobalt

| Item | TSUS No. | Most favored nation (MFN) |  | Non-MFN |
|---|---|---|---|---|
|  |  | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Alloys, unwrought | 632.86 | 9% ad valorem | 9% ad valorem | 45% ad valorem. |
| Chemical compounds: |  |  |  |  |
| Oxide | 418.60 | 1.2 cents per pound. | 1.2 cents per pound. | 20 cents per pound. |
| Sulfate | 418.62 | 1.4% ad valorem | 1.4% ad valorem | 6.5% ad valorem. |
| Other | 418.68 | 4.7% ad valorem | 4.2% ad valorem | 30% ad valorem. |
| Ore and concentrate | 601.18 | Free | Free | Free. |
| Unwrought metal, waste and scrap | 632.20 | do | do | Do. |

## WORLD REVIEW

After months of negotiations, Falconbridge Ltd., a Canadian cobalt and nickel producer, concluded a supply contract that resulted in a number of changes in the structure of the international cobalt market. Under the terms of the 14-year contract, Falconbridge was to receive the majority of the matte produced by Bamangwato Concessions Ltd. (BCL), of Botswana. All of the matte had formerly been sent to the AMAX Nickel refinery in Louisiana. BCL reportedly requested termination of the AMAX Nickel contract because of a better offer from Falconbridge. The termination of the contract was subject to a number of conditions, which included compensation for the balance of AMAX Nickel's 15-year contract and for the cost of the impending closure of the Port Nickel refinery. BCL matte production was estimated at 57,000 short tons per year. The contract provided for the delivery to the Faconbridge refinery at Kristiansand, Norway, of about 7,000 tons of matte in 1985, 23,000 tons in 1986, and its full allocation of 46,000 tons annually from 1987 until the end of the contract in 1999. The feedstock was to enable Falconbridge to produce an additional 500,000 pounds of cobalt in 1987 without installing additional cobalt production capacity. The Falconbridge acquisition of the BCL matte was due, in part, to a decision by Western Platinum Ltd. (Wesplat) of the Republic of South Africa, to build its own refinery, ending the practice of sending its matte to Kristiansand for refining. The remaining 11,000 tons per year of BCL matte was slated to go to Rio Tinto (Zimbabwe) Ltd. (RTZ). After the failure of AMAX Nickel to have the Agnew matte refined elsewhere, AMAX Nickel agreed to terms for the sale of the majority of the matte to Sherritt Gordon Mines Ltd., of Canada, and to Outokumpu Oy, of Finland. At yearend, the disposition of the remainder of the Agnew matte was undecided.

**Albania.**—The scheduled completion of a nickel-cobalt refinery was delayed owing to a scarcity of hydroelectric power. The facility, which was being built by Salzgitter Industriebau GmbH, a West German firm, was expected to be completed in late 1986.

**Brazil.**—Cia. Níquel Tocantins increased its cobalt production by signing a toll refining agreement with Falconbridge. The 2-year contract called for approximately 120,000 pounds of cobalt per year to be refined at Falconbridge's refinery in Norway. Tocantins' 1985 cobalt production capacity of about 150,000 pounds per year at its São Paulo facility was expected to double by yearend 1986.

**Canada.**—Inco Ltd. and Falconbridge, both cobalt and nickel producers, introduced voluntary early retirement plans in an effort to reduce the number of workers at their Sudbury, Ontario, facilities. In addition, Inco was trying to reduce the work force at its Port Colborne, Ontario, refinery.

The Ontario, Canada, Provincial government issued new standards on the emissions of sulfur dioxide, which were to have a direct impact on two cobalt and nickel producers. Inco was told to achieve a target level at its Sudbury operation of 292,000 tons per year of sulfur dioxide by reducing emissions by 77% from its 1980 base level of 1.273 million tons per year. Inco had already reduced its emissions by adjusting its feed to reduce the quantity of sulfur contained in the concentrates. Any further reduction, however, was to come from the use of new technology and was expected to be expensive. Falconbridge was to be required to reduce sulfur dioxide emissions from its Sudbury operations from the then-current 170,000 tons per year to 110,000 tons per year.

Inco improved its productivity by 13% in

1985, following a record 18% increase in 1984. The improvements were effected through the increased application of safer, less costly bulk mining methods and the use of automated mining equipment. This was combined with productivity improvements at smelting and refining facilities. In 1985, nearly 80% of the company's Canadian ore was mined using bulk methods, up from 70% in 1984.

**China.**—The West German firm of Friedrich Krupp GmbH secured a contract to oversee the construction of a cobalt and tungsten refinery. The contract called for Krupp to supply machinery, equipment, and technical expertise in a 2-year project to result in a plant to produce cobalt, tungsten carbide, and cemented carbides.

**Cuba.**—The Punta Gorda nickel-cobalt plant was reported to have come on-stream in December.

**Indonesia.**—Ni-Cal Technology Ltd., Bermuda, was reported to have signed a letter of intent with P.T. Aneka Tambang (Antam), an Indonesian mining company, to form a joint venture to build and operate a nickel and cobalt processing plant in Indonesia. Construction of the facility, which was expected to be able to process 850 tons of ore per day, was to begin after a 4-month feasibility study was completed. The facility was to be located at Antam's laterite mining operation on Gebe Island.

**Japan.**—In September, Japanese cobalt refinery production returned to a near-capacity level of over 5 million pounds per year for the first time since 1982. The production increase came after resumption of shipments of Philippine feed material to Sumitomo Metal Mining Co. Ltd.

**South Africa, Republic of.**—Wesplat commissioned a refinery at its Marikana Mine, near Rustenburg. The new refinery was built to recover cobalt, nickel, and copper from matte that had previously been sent to the Falconbridge refinery in Norway for treatment.

**U.S.S.R.**—A 5-year plan was concluded in Norilsk, which resulted in a 50% increase in cobalt production. Plans called for an additional increase in production in 1986.

**Zaire.**—Because of its efforts to maintain an unofficial producer price of $11.70 per pound for electrolytic cobalt, Zaire lost a significant share of the U.S. market in 1985. Based solely on imports, after quantities of cobalt destined for the National Defense Stockpile were subtracted, its share fell from 54% in 1984 to 27% in 1985. These figures, however, did not tell the whole story as there were strong indications that Zaire had built up its cobalt stocks in the United States in late 1984 in anticipation of transportation difficulties in the Republic of South Africa. Most of the cobalt exported by Zaire during the year was shipped through the Republic of South Africa.

**Zimbabwe.**—RTZ, having secured a source of feedstock from BCL, reopened its Eiffel Flats refinery in August. The facility had been closed since September 1983, when its supply of matte from BCL was diverted to the United States. RTZ was said to have reached an agreement on a 10-year contract to toll refine the BCL matte for Centametall AH, a Swiss trading company.

### Table 9.—Cobalt: World production, by country[1]

(Short tons)

| Country | Mine output, metal content[2] | | | | | Metal[3] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1981 | 1982 | 1983 | 1984[p] | 1985[e] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
| Albania[e] | 380 | [r]440 | [r]500 | [r]660 | 660 | -- | -- | -- | -- | -- |
| Australia[4] | 1,616 | 1,631 | [r] [e]1,300 | [r] [e]1,200 | 920 | -- | -- | -- | -- | -- |
| Botswana | 280 | 280 | 246 | [e]250 | 250 | -- | -- | -- | -- | -- |
| Brazil | NA | NA | 131 | [e]110 | 110 | -- | -- | -- | -- | -- |
| Canada[5] | 2,293 | 1,548 | 1,747 | 2,563 | 3,390 | 1,003 | 1,148 | 1,460 | 2,340 | 2,950 |
| Cuba | 1,890 | 1,650 | 1,787 | 1,540 | 1,570 | -- | -- | -- | -- | -- |
| Finland | 1,140 | [r]1,142 | 1,141 | 1,050 | 1,050 | 1,355 | 1,604 | 1,709 | 1,602 | 1,600 |
| France | -- | -- | -- | -- | -- | 493 | [r]626 | 144 | 128 | 120 |
| Germany, Federal Republic of[e] | -- | -- | -- | -- | -- | 160 | 160 | 110 | 110 | 110 |
| Japan | -- | -- | -- | -- | -- | 2,669 | 2,141 | 1,512 | 998 | [e]1.408 |
| Morocco | 870 | 873 | -- | -- | -- | -- | -- | -- | -- | -- |
| New Caledonia[7] | 407 | 299 | [r] [e]440 | [r] [e]550 | 750 | -- | -- | -- | -- | -- |
| Norway | -- | -- | -- | -- | -- | 1,592 | 1,094 | 969 | 1,313 | [e]1,804 |
| Philippines | 1,099 | [r]514 | 182 | 71 | [e]977 | -- | -- | -- | -- | -- |
| U.S.S.R.[e] | 2,400 | 2,500 | 2,600 | 2,900 | 3,000 | 4,700 | 4,700 | 5,000 | 5,200 | 5,300 |
| United Kingdom[e] [8] | -- | -- | -- | -- | -- | 800 | 400 | -- | -- | -- |
| United States | -- | -- | -- | -- | -- | 447 | 508 | 103 | -- | -- |
| Zaire | [e]17,000 | [e]12,460 | [e]12,460 | [r] [e]19,800 | 22,000 | 12,262 | [r]6,035 | 5,908 | 10,003 | 11,000 |
| Zambia | 4,410 | 3,584 | 3,527 | 5,090 | 5,090 | 2,833 | [r]2,696 | 2,653 | 3,828 | 3,830 |
| Zimbabwe | [e]110 | [e]110 | [e]85 | [e]85 | 100 | 104 | 109 | 81 | 86 | 95 |
| Total | 33,895 | [r]27,031 | 26,146 | 35,869 | 89,867 | 28,418 | [r]21,221 | 19,649 | 25,608 | 28,217 |

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1] Table includes data available through May 20, 1984.

[2] Figures represent recoverable cobalt content. In addition to the countries listed, Bulgaria, Cyprus, the German Democratic Republic, Greece, Indonesia, Poland, the Republic of South Africa, Spain, and Uganda are known to produce ores that contain cobalt. Information is inadequate for reliable estimates of output levels. Other copper and/or nickel producing nations may also produce ores containing cobalt as a byproduct component, but recovery is small or nil.

[3] Figures represent elemental cobalt recovered unless otherwise specified. In addition to the countries listed, Czechoslovakia presumably recovers cobalt from Cuban nickel-cobalt oxide and oxide sinter; Belgium has imported small quantities of partly processed materials containing cobalt, but available information is inadequate to form reliable estimates of cobalt recovery from these materials.

[4] Australia does not produce cobalt. Figures represent quantities of cobalt contained in intermediate metallurgical products (cobalt oxide and nickel-cobalt sulfide). Actual quantities of cobalt mined were as follows in short tons: 1981—3,199; 1982—3,911; 1983—2,521; 1984—2,340; and 1985—1,800 (estimated).

[5] Actual output is not reported. Data for mine output are total cobalt content of all products derived from ores of Canadian origin, including cobalt oxide shipped to the United Kingdom for further processing, and nickel-copper-cobalt matte shipped to Norway for further processing. Data presented for metal output represent the output within Canada of metallic cobalt from ores of both Canadian and non-Canadian origin.

[6] Reported figure.

[7] Series reflects recovery from ores and intermediate metallurgical products exported from New Caledonia to France, Japan, and the United States. The estimated content of total ores mined is as follows, in short tons: 1981—3,074; 1982—2,351; 1983—3,465; 1984—4,513; and 1985—5,720.

[8] Estimated recovery of elemental cobalt in refined cobalt oxides and salts from intermediate metallurgical products originating in Canada.

## TECHNOLOGY

The Bureau of Mines performed a study of the availability of cobalt from market economy countries. In the study, 97 deposits were analyzed.[3] Since nearly all cobalt produced has been a byproduct of nickel or copper mining, the report focused on those deposits. An economic evaluation on each deposit was performed to determine its cost of production. The study also investigated the interrelationship of the recovery of cobalt and its associated primary commodities.

Bureau researchers continued to improve the process for recovering cobalt from copper leach solutions.[4] Among the most significant improvements were the reduction of the quantity of resin needed to process the solution, thereby significantly reducing the cost of the process, and the determination that solvent extraction procedures produced a cobalt sulfate solution suitable for electrowinning. The latter procedures remove impurities from the column eluates, separate the cobalt and nickel, and concentrate the cobalt.

Other Bureau research was conducted on the recovery of cobalt from Missouri lead ores.[5] These ores were unique because they represented the only domestic cobalt resource being mined. Froth flotation was used to recover up to 65% of the cobalt found in the mill tailings.

The Bureau of Mines developed and demonstrated an ammoniacal sulfate leach process for recovering cobalt and nickel from low-grade domestic laterite deposits. One of the process steps, solvent extraction of cobalt, required the reduction of hexammine complexes of cobalt in an ammoniacal leach solution. Previously, this reduction had been accomplished using cobalt metal shot in a column. The Bureau published a report that presented experimental results and an economic evaluation comparing two alternate techniques with that of the shot column.[6] The first technique involved an electrolytic reduction cell with an extended surface area cathode, whereas the second was direct electrowinning from purified leach solution using a cell with a fluid bed cathode. The second alternative eliminated the conventional solvent extraction-electrowinning steps. The operating costs for the shot column, and for electrolytic reduction, were essentially the same at $0.54 per pound of cobalt, but the cost of direct electrowinning, $1.71 per pound of cobalt, eliminated this method as a practical alternative.

Another Bureau report described an investigation of factors influencing economic viability of a proposed system to mine and process cobalt-containing manganese nodules.[7] The report concluded that nodule mining would not take place in the foreseeable future without significant financial incentives, such as price supports, tax breaks, or other programs.

The Bureau published a summary of a 5-year program sponsored by the National Oceanic and Atmospheric Administration to devise waste management plans for the processing of cobalt-containing manganese nodules.[8] Studies included summary descriptions of Pacific manganese nodules, process options and flowsheets, methods for characterizing nodules and their tailings, and results of analyses of laboratory and pilot plant generated tailings.

The Bureau of Mines investigated the effects of hydrogen chloride concentration and solution temperature on the solubility and crystal form of the chlorides of cobalt, nickel, and manganese when sparged with hydrogen chloride gas.[9] The results of the investigation indicated an improved method for the separation of cobalt and nickel when dissolved in hydrochloric acid.

As part of its continuing efforts to reduce U.S. dependence on foreign sources for strategic and critical metals, the Bureau of Mines conducted research to improve the technology for recycling these metals from superalloy scrap. The research approach involved melting and casting superalloy scrap into soluble anodes for electrodeposition of cobalt-nickel alloys by controlled potential electrolysis. A report was published that described the experimental results from tests using alloy anodes cast from elemental cobalt, nickel, and chromium, the main constituents of superalloys.[10] Baseline data from these tests were necessary before detailed experiments could be conducted on the more complex superalloy scrap. The report assessed the effects of cathode potential and other parameters on cathode current efficiency, alloy deposit composition, and deposition potential at a cell temperature of 55° C.

The Bureau investigated technology for increasing the leaching rate of bulk superalloy scrap by treating the scrap with zinc.[11] The treatment, which included dissolution of the superalloy scrap in molten zinc and vacuum distillation of the zinc for reuse, dramatically increased the leaching rate of superalloys.

Another metals recycling report was published that described Bureau of Mines work on the rapid identification and sorting of scrap metals.[12] One method, spark testing, was the examination of the pattern of sparks that resulted when a metal or alloy was ground on an abrasive wheel. The primary drawback of using this method was the necessity for having experienced sorters. Researchers developed a spectrophotometric method that eliminated the need for experienced sorters. The spectra of several alloys were measured, and it was found that the differences in the spectra were sufficient for identification.

A fundamental study was performed on the recovery of cobalt and nickel from iron-based molten alloys by using metal solvents.[13] The aim of this work was to investigate a pyrometallurgical process to directly recover cobalt and nickel from iron-based alloys. The results indicated that further research would be required to find better solvent systems for the recovery of cobalt.

Bureau of Mines research was conducted to devise a procedure for treating cobalt-nickel-bearing magnetic alloy grinding sludge to remove detrimental contaminants and produce an alloy powder for recycling.[14] The technique consisted of (1) treatment with solvent to remove most of the sulfur and oil contamination, (2) drying, light grinding, sizing, and magnetic separation of a major portion of the grinding media, (3) controlled oxidation roasting to remove residual sulfur and carbon, and (4) hydrogen reduction of metal oxides. Overall, more than 95% of the cobalt, nickel, and iron and about 90% of the copper were recovered from the starting sludge sample.

AMAX Inc., Greenwich, CT, announced that Compagnie Française d'Entreprises Minières, Metallurgiques et, d'Investissements (COFREMMI), its joint venture with Bureau de Recherches Géologiques et Minières (BRGM), the state-owned mining company of France, had made available for licensing a high-pressure, sulfuric acid leach process it had developed for the treatment of lateritic ores.[15] The COFREMMI process, a result of 15 years of extractive research and development, was said to provide high cobalt and nickel recovery rates and low energy and operating costs, while being highly adaptable to a variety of ores.

A process was developed at Argonne National Laboratory for recovering cobalt and manganese from low- and medium-grade ores.[16] In tests, which focused on deep sea nodules, the method extracted nearly 100% of metal values. The process was based on ores being dissolved into a molten salt mixture from which metals were separated by electrolysis. By proper control of the electrolysis potential, cobalt was able to be selectively recovered even in the presence of manganese and other transition elements.

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# Columbium and Tantalum

## By Larry D. Cunningham[1]

The United States remained dependent on imports of columbium and tantalum, and there continued to be no domestic production of either mineral. Imports for consumption of tantalum mineral concentrates declined significantly, reflecting a lack of activity in the spot tantalite market. Tantalum materials purchased for the National Defense Stockpile (NDS) in 1983 and 1984 were delivered and recorded as stockpile inventory. In July, the President approved National Security Council (NSC) recommendations for modernizing the stockpile. The Cabot Corp. announced a restructuring program to sell all its metals businesses except columbium and tantalum, while Mallinckrodt Inc. was forced to shut down its columbium and tantalum operations at yearend.

Domestic production and value of ferrocolumbium continued downward. However, reported consumption of columbium in the form of ferrocolumbium and nickel columbium continued to increase. Columbium consumption in all steel end-use categories increased, with the exception of stainless and heat-resisting steels. Demand for tantalum was down. Reported shipments of tantalum products and sales of tantalum capacitors were both down significantly compared with levels in 1984.

Columbium price quotations were unchanged, whereas most tantalum concentrates and related product prices declined. Net trade for both columbium and tantalum continued at a deficit, with overall trade volume and value lower than in 1984 for both exports and imports.

Thailand's chemical plant for the processing of columbium- and tantalum-bearing materials was completed. Commercial production is planned to begin by yearend 1986.

**Domestic Data Coverage.**—Domestic production data for ferrocolumbium are devel-

**Table 1.—Salient columbium statistics**

(Thousand pounds of columbium content unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Mine production of columbium-tantalum concentrates | ([1]) | ([1]) | -- | -- | -- |
| Releases from Government excesses | -- | -- | -- | -- | -- |
| Consumption of raw materials | 1,983 | [e]1,900 | [e]1,900 | [e]2,600 | [e]2,000 |
| Production of ferrocolumbium | 1,145 | W | W | W | W |
| Consumption of primary products: Ferrocolumbium and nickel columbium[e] | 6,244 | 3,679 | 4,318 | 5,399 | 5,968 |
| Exports: Columbium metal, compounds, alloys (gross weight)[e] | 150 | 100 | 100 | 100 | 120 |
| Imports for consumption: | | | | | |
| Mineral concentrates[e] | 1,050 | 580 | 730 | 1,790 | 1,290 |
| Columbium metal and columbium-bearing alloys[e] | ([2]) | 9 | 2 | 10 | 1 |
| Ferrocolumbium[e] | 6,068 | 3,128 | 2,539 | 4,343 | 4,699 |
| Tin slags[e] [3] | 842 | 636 | W | W | W |
| World: Production of columbium-tantalum concentrates[e] | [r]32,662 | 23,334 | [r]18,911 | [r]32,833 | 35,044 |

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1] A small unreported quantity was produced.

[2] Less than 1/2 unit.

[3] Receipts reported by consumers; includes synthetic concentrates and other miscellaneous materials, after deduction of reshipments.

## Table 2.—Salient tantalum statistics

(Thousand pounds of tantalum content unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Mine production of columbium-tantalum concentrates | ([1]) | ([1]) | -- | -- | -- |
| Releases from Government excesses | -- | -- | -- | -- | -- |
| Consumption of raw materials | 1,269 | [e]800 | [e]900 | [e]1,300 | [e]1,100 |
| Exports: | | | | | |
| Tantalum ores and concentrates (gross weight)[2] | 99 | 235 | 121 | 156 | 122 |
| Tantalum metal, compounds, alloys (gross weight) | 205 | 382 | 211 | 352 | 369 |
| Tantalum and tantalum alloy powder (gross weight) | 97 | 115 | 123 | 151 | 143 |
| Imports for consumption: | | | | | |
| Mineral concentrates[e] | 650 | 440 | 180 | 680 | 230 |
| Tantalum metal and tantalum-bearing alloys[3] | 34 | 71 | 27 | 47 | 32 |
| Tin slags[e] [4] | 896 | 576 | W | W | W |
| World: Production of columbium-tantalum concentrates[e] | [r]889 | [r]627 | [r]690 | [r]739 | 622 |

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1] A small unreported quantity was produced.

[2] Includes reexports.

[3] Exclusive of waste and scrap.

[4] Receipts reported by consumers; includes synthetic concentrates and other miscellaneous materials, after deduction of reshipments.

## Table 3.—Columbium and tantalum materials in Government inventories as of December 31, 1985

(Thousand pounds of columbium or tantalum content)

| Material | Stockpile goals | National Defense Stockpile inventory | | |
|---|---|---|---|---|
| | | Stockpile-grade | Nonstockpile-grade | Total |
| Columbium: | | | | |
| Concentrates | 5,600 | 1,150 | 869 | [1]2,019 |
| Carbide powder | 100 | 21 | -- | 21 |
| Ferrocolumbium | -- | 598 | 333 | [1]931 |
| Metal | -- | 45 | -- | [1]45 |
| Total | ([2]) | 1,814 | 1,202 | 3,016 |
| Tantalum: | | | | |
| Minerals | 8,400 | 1,686 | 1,152 | [3]2,838 |
| Carbide powder | -- | 29 | -- | [3]29 |
| Metal | -- | 201 | ([4]) | [3]201 |
| Total | ([2]) | 1,916 | 1,152 | 3,068 |

[1] All surplus ferrocolumbium and columbium metal were used to offset the columbium concentrates shortfall. Total offset was 1,148,000 pounds.

[2] Overall goals, on a recoverable basis, total 4,850,000 pounds for the columbium metal group and 7,160,000 pounds for the tantalum metal group.

[3] All surplus tantalum carbide powder and tantalum metal were used to offset the tantalum minerals shortfall. Total offset was 271,000 pounds.

[4] 100 pounds.

Sources: Federal Emergency Management Agency and General Services Administration.

oped by the Bureau of Mines from the annual voluntary survey for ferroalloys. Of the four domestic operations to which a survey request was sent, all responded, representing 100% of total production. Ferrocolumbium production data are withheld for 1985 to avoid disclosing company proprietary data.

**Legislation and Government Programs.**—The NDS goals for columbium and tantalum materials did not change during 1985, and there were no sales of stockpile excess materials.

Tantalum materials contracted for in late 1983 and early 1984 from Greenbushes Tin Ltd. of Australia and Amalgamet Inc., Bomar Resources Inc., and Norore Corp., all of New York City, were delivered and recorded as stockpile inventory. Yearend stockpile inventories reported by the General Services Administration for contained columbium in concentrates and contained tantalum in minerals increased by 213,000 pounds and 254,000 pounds, respectively.

However, inventories of all columbium and tantalum materials continued to be considerably below their respective goals. As of yearend 1985, under the offset concept, 57% of the goal for columbium concentrates and 37% of the goal for tantalum minerals were met.

On July 8, the President approved NSC recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, columbium would be categorized in tier II, and the goal would be 2,532,419 pounds of columbium metal equivalent. Tantalum would be categorized in both tier I and tier II, and the goals would be 1,900,700 pounds and 1,023,320 pounds of tantalum metal equivalent, respectively. At yearend this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

The Environmental Protection Agency (EPA) set final rules for new effluent limitation guidelines and standards for nonferrous metals-forming operations, based on "best practicable, available, and demonstrated technologies to handle industry's waste water discharges."[2] The standards include columbium and tantalum and are part of EPA's water pollution effluent guidelines program under the Clean Water Act for Nonferrous Metals.

## DOMESTIC PRODUCTION

No domestic mineral concentrate production of either columbium or tantalum was reported in 1985.

Domestic production of ferrocolumbium, expressed as contained columbium, was virtually unchanged from that of 1984. Value of ferrocolumbium production decreased to an estimated $8.7 million. The regular grade continued to be favored over the high-purity grade of ferrocolumbium in the production mix.

Tantalum content of raw materials consumed by processors in the production of tantalum compounds and metals was estimated to be about 1.1 million pounds, down by 15% from that of 1984. In addition, consumption of purchased metal scrap was estimated at about 90,000 pounds.

On December 19, Avon Products Inc. entered into an agreement with International Minerals & Chemical Corp. (IMC) to sell its Mallinckrodt Div. for $675 million in cash.[3] The acquistion of Mallinckrodt, a specialty chemicals and medical product operation, reportedly reflects IMC's long-term strategy to broaden the company's sources of income beyond its agricultural businesses. At midyear, Mallinckrodt announced that its long-term tolling arrangement with NRC Inc., for conversion of columbium- and tantalum-bearing concentrates, would not be renewed in 1986.[4] By yearend, Mallinckrodt, representing about one-third of the domestic tantalum raw material processing capacity, was forced to shut down its columbium and tantalum operations because alternative tolling arrangements could not be made.

On October 16, Cabot announced a restructuring program to sell those assets not meeting the company's financial performance objectives.[5] Cabot's divestiture program includes the Westar natural gas transmission system and all specialty metals businesses, except columbium and tantalum. The businesses to be sold represent approximately 40% of Cabot's total assets. The company estimates that its work force will be reduced by more than 2,000 employees worldwide upon completion of the program. With metal interest directed at columbium and tantalum, Cabot commissioned a $3 million vacuum-arc remelt furnace in Boyertown, PA. The furnace will be used to produce columbium metal and columbium-titanium alloys for superconducting magnet applications.[6]

**Table 4.—Major domestic columbium and tantalum processing and producing companies in 1985**

| Company | Plant location | Products[1] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Metal[2] | | Carbide | | Oxide and/or salts | | FeCb and/or NiCb |
| | | Cb | Ta | Cb | Ta | Cb | Ta | |
| Avon Products Inc.: Mallinckrodt Inc. | St. Louis, MO | -- | -- | -- | -- | X | X | -- |
| Cabot Corp. | Boyertown, PA | X | X | -- | -- | X | X | -- |
| Do | Revere, PA | -- | -- | -- | -- | -- | -- | X |
| Fansteel Inc | Muskogee, OK | X | X | -- | -- | X | X | -- |
| Do | North Chicago, IL | -- | X | -- | -- | -- | -- | -- |
| Kennametal Inc | Latrobe, PA | -- | X | X | X | -- | -- | -- |
| Metallurg Inc.: Shieldalloy Corp. | Newfield, NJ | -- | X | X | X | -- | -- | X |
| NRC Inc.[3] | Newton, MA | X | X | -- | -- | -- | -- | -- |
| Reading Alloys Inc | Robesonia, PA | -- | -- | -- | -- | -- | -- | X |
| Teledyne Inc.: Teledyne Wah Chang Albany Div. | Albany, OR | X | X | -- | -- | X | -- | X |

X Indicates processor and/or producer.

[1] Cb, columbium; Ta, tantalum; FeCb, ferrocolumbium; NiCb, nickel columbium.

[2] Includes miscellaneous alloys.

[3] Jointly owned by Omicron Holdings Inc. and Hermann C. Starck Berlin.

## CONSUMPTION, USES, AND STOCKS

Overall reported consumption of columbium as ferrocolumbium and nickel columbium rose by about 10%. Consumption of columbium by the steelmaking industry rose 15%, with the percent of columbium usage per ton of steel produced rising significantly. Consumption in all steel end-use categories was up with the exception of the stainless and heat-resisting steels, which experienced a slight decline. Consumption in carbon steels increased by about 18%. Columbium demand in high-strength low-alloy steels advanced by more than 20%, exceeding 2 million pounds for the first time since 1981.

A new columbium-base nitrided alloy, Tribocor 532N (columbium, 30% titanium, 20% tungsten), was developed and test-marketed by Fansteel Inc. Potential applications for the alloy, which is suited for environments involving both wear and corrosion, include seal rings, oil well components, and spray nozzles.

Demand for columbium in superalloys declined slightly. However, that portion used in the form of nickel columbium continued to rise by nearly 30% to about 540,000 pounds, reflecting a shift from ferrocolumbium.

The Tantalum Producers Association reported a 21% drop in overall tantalum shipments, indicating a sizable decline in the market. The powder and anodes and the mill products segments, both of which had experienced significant growth in 1984, declined 31% and 19%, respectively. Tantalum for cemented carbide dropped 30%. The decline was influenced by the growing popularity of coated cutting tools and by the automotive industry's emphasis on producing smaller vehicles, which required less metal cutting. Tantalum as an alloy additive was the only major segment in the market showing an increase and was up by 63%. Tantalum continues to be a key and important strengthening element in many nickel- and cobalt-base alloys for application in the growing market for heat-resisting turbine engine components.

Factory sales of tantalum capacitors decreased by over 20% from the record-high sales in 1984, as reported by the Electronic Industries Association. Weak demand for tantalum capacitor products by computer manufacturers, a major market, contributed substantially to the decline. The Sprague Electric Co. conducted a restructuring program throughout 1985 to reduce the number of capacitor manufacturing facilities through consolidation of operations. The consolidation was done without a significant loss of production capacity, but employment at the company was reduced by 26%.[7]

Data on aggregate stocks of columbium and tantalum raw materials reported by processors for 1985 were incomplete at the time this chapter was prepared. Aggregate stocks of columbium and tantalum raw materials reported by processors for yearend 1984 were both down from yearend 1983, by about 30% for columbium and by more than 15% for tantalum.

### Table 5.—Reported shipments of columbium and tantalum materials

(Pounds of metal content)

| Material | 1984 | 1985 |
|---|---|---|
| Columbium products: | | |
| Compounds including alloys | 941,820 | 1,149,120 |
| Metal including worked products | 529,800 | 404,300 |
| Other | 500 | 300 |
| Total | 1,472,120 | 1,553,720 |
| Tantalum products: | | |
| Oxides and salts | 45,900 | 27,600 |
| Alloy additive | 86,630 | 141,420 |
| Carbide | 128,760 | 90,210 |
| Powder and anodes | 665,500 | 459,800 |
| Ingot (unworked consolidated metal) | 9,500 | 220 |
| Mill products | 307,600 | 249,500 |
| Scrap | 39,000 | 48,300 |
| Total | 1,282,890 | 1,017,050 |

Source: Tantalum Producers Association.

### Table 6.—Consumption, by end use, and industry stocks of ferrocolumbium and nickel columbium in the United States

(Pounds of contained columbium)[1]

| | 1984 | 1985 |
|---|---|---|
| END USE | | |
| Steel: | | |
| Carbon | 1,463,886 | 1,720,554 |
| Stainless and heat-resisting | 951,020 | 935,469 |
| Full alloy | (2) | (2) |
| High-strength low-alloy | 1,693,464 | 2,056,532 |
| Tool | (3) | (3) |
| Unspecified | 27,941 | 29,135 |
| Total | 4,136,311 | 4,741,690 |
| Superalloys | 1,240,295 | 1,204,249 |
| Alloys (excluding alloy steels and superalloys) | 19,454 | 21,716 |
| Miscellaneous and unspecified | 3,185 | -- |
| Total consumption | 5,399,245 | 5,967,655 |
| STOCKS | | |
| Dec. 31: | | |
| Consumer | W | W |
| Producer[4] | W | W |
| Total stocks[e] | 950,000 | 720,000 |

[e] Estimated. W Withheld to avoid disclosing company proprietary data; included in "Total stocks."

[1] Includes columbium and tantalum in ferrotantalum-columbium, if any.

[2] Small; included with "Steel: High-strength low-alloy."

[3] Included with "Steel: Unspecified."

[4] Ferrocolumbium only.

## PRICES

The published price for pyrochlore concentrates and columbium products based on them remained unchanged. The price for pyrochlore concentrates produced in Canada by Niobec Inc. continued to be quoted at $3.25 per pound of contained columbium pentoxide ($Cb_2O_5$), f.o.b. Canada, for concentrates with a nominal content of 57% to 62% $Cb_2O_5$. The quoted spot price of regular-grade ferrocolumbium containing 63% to 68% columbium was unchanged at $5.66 per pound of contained columbium, f.o.b. shipping point.

The quoted price for high-purity ferrocolumbium containing 62% to 68% columbium continued to be quoted at $17.70 per pound of contained columbium, f.o.b. shipping point. Nickel columbium was reported to be selling at yearend for about $17 per pound of contained columbium. Columbium metal price quotes were unchanged. The spot price for columbite concentrates was quoted throughout 1985 at $3.50 to $5.00 per pound of combined $Cb_2O_5$ and tantalum pentoxide ($Ta_2O_5$), c.i.f. U.S. ports. Columbium oxide was reported to be selling at yearend for about $6.50 per pound of oxide.

Most tantalum prices were down from the 1984 levels, with declining tantalum demand and a continued lack of activity in the spot tantalite market. The published spot market price for tantalite, on the basis of 60% combined $Cb_2O_5$ and $Ta_2O_5$, c.i.f. U.S. ports, which began the year at $30 to $32, was being quoted at $21 to $24.50 by yearend, the lowest level since first quarter 1983. The contract price for tantalite from the Canadian tantalum producer, Tantalum Mining Corp. of Canada Ltd. (Tanco), quoted at $45 per pound of contained pentoxide since midyear 1982, was suspended on January 1, 1985. The contract price for tantalite from Greenbushes in Australia remained suspended. Published price quotations for tantalum mill products and powders were down by 10% and 20%, respectively.

## FOREIGN TRADE

Net trade continued at a deficit for both columbium and tantalum. Overall trade volume and value were down for both exports and imports. Exports and reexports of tantalum ores and concentrates declined more than 20% to 122,000 pounds valued at $1.6 million. The Federal Republic of Germany, Japan, and the Netherlands were the principal recipients, altogether accounting for more than 90% of total shipments.

Imports of raw materials and intermediates, such as ferrocolumbium and columbium oxide, exceeded the value of exports of upgraded forms of columbium and tantalum by almost 80%. Imports for consumption from Brazil included more than 7.2 million pounds of ferrocolumbium with a value of $22.2 million, compared with 6.7 million pounds valued at $20.4 million in 1984. Imports for consumption of columbium oxide from Brazil decreased almost 40% to 725,000 pounds valued at $4.7 million, compared with 1.2 million pounds valued at $6.8 million in 1984. Contained in the columbium oxide imports were an estimated 14,000 pounds of tantalum oxide valued at about $500,000. Estimated data for the ferrocolumbium and the columbium and tantalum oxides were based on entries in nonspecific classes.

Imports for consumption of columbium mineral concentrates declined more than 10% from those of 1984. Average unit value for overall imports declined by 13% owing to the low unit value of concentrates from Canada, which was about 97% of the total quantity. Imports were estimated to contain 1.18 million pounds of columbium and 5,000 pounds of tantalum at an average grade of approximately 59% $Cb_2O_5$ and less than 1% $Ta_2O_5$.

Imports for consumption of tantalum mineral concentrates declined by 66% with average unit value up nearly 30%. Brazil and Canada were the leading sources, together providing about 60% of both total quantity and total value. The imports from Canada were the first since 1982. Imports were estimated to contain 225,000 pounds of tantalum and 110,000 pounds of columbium at an average grade of approximately 38% $Ta_2O_5$ and 21% $Cb_2O_5$.

Data on receipts of raw materials other than mineral concentrates were incomplete.

Imports for consumption of columbium-tantalum synthetic concentrates totaled 2.75 million pounds with a value of $18.4 million, compared with 2.1 million pounds valued at $13.7 million in 1984. These figures are not included in the salient statistics data.

## Table 7.—U.S. foreign trade in columbium and tantalum metal and alloys, by class

(Thousand pounds, gross weight, and thousand dollars)

| Class | 1984 | | 1985 | | Principal destinations and sources, 1985 |
|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | |
| **EXPORTS**[1] | | | | | |
| Tantalum: | | | | | |
| Powder | 151 | 17,026 | 143 | 15,188 | France 42, $4,505; Japan 26, $2,894; West Germany 23, $2,831; United Kingdom 16, $1,879. |
| Unwrought and waste and scrap | 252 | 10,050 | 305 | 8,304 | West Germany 185, $5,180; Japan 13, $1,060; Belgium-Luxembourg 25, $785; France 9, $574. |
| Wrought | 100 | 13,099 | 64 | 9,339 | Japan 17, $2,869; United Kingdom 19, $2,690; West Germany 11, $1,514; France 8, $1,247. |
| Total | XX | 40,175 | XX | 32,831 | West Germany $9,500; Japan $6,800; France $6,300; United Kingdom $4,600.[2] |
| **IMPORTS FOR CONSUMPTION** | | | | | |
| Columbium: | | | | | |
| Ferrocolumbium[e] | 6,682 | 20,445 | 7,229 | 22,207 | All from Brazil. |
| Unwrought metal and waste and scrap | 7 | 125 | 8 | 31 | United Kingdom 7, $21; West Germany ([3]), $10. |
| Unwrought alloys | 13 | 103 | ([3]) | 2 | All from Japan. |
| Wrought | ([3]) | 35 | ([3]) | 8 | All from West Germany. |
| Tantalum: | | | | | |
| Waste and scrap | 183 | 4,866 | 134 | 5,518 | West Germany 51, $2,770; Belgium-Luxembourg 13, $782; Netherlands 8, $523; France 15, $356. |
| Unwrought metal | 46 | 4,878 | 22 | 2,282 | West Germany 16, $1,776; Belgium-Luxembourg 5, $439; United Kingdom 1, $63. |
| Unwrought alloys | 1 | 33 | -- | -- | |
| Wrought | 1 | 48 | 9 | 254 | West Germany 1, $200; Belgium-Luxembourg 8, $49. |
| Total | XX | 30,533 | XX | 30,302 | Brazil $22,200; West Germany $4,800; Belgium-Luxembourg $1,300; Netherlands $900.[2] |

[e] Estimated. XX Not applicable.

[1] For columbium, data on exports of metal and alloys in unwrought and wrought form, including waste and scrap, are not available; included in basket category.

[2] Rounded.

[3] Less than 1/2 unit.

Sources: Bureau of the Census and Bureau of Mines.

## Table 8.—U.S. imports for consumption of columbium mineral concentrates, by country

(Thousand pounds and thousand dollars)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Gross weight | Value | Gross weight | Value |
| Brazil | 143 | 431 | -- | -- |
| Canada | 2,498 | 4,089 | 2,821 | 4,496 |
| Germany, Federal Republic of[1] | 17 | 38 | -- | -- |
| Malaysia | 105 | 163 | -- | -- |
| Netherlands[1] | 8 | 24 | -- | -- |
| Nigeria | 495 | 1,284 | 77 | 177 |
| Total[2] | 3,265 | 6,030 | 2,899 | 4,673 |

[1] Presumably country of transshipment rather than original source.

[2] Data may not add to totals shown because of independent rounding.

Sources: Bureau of the Census and Bureau of Mines.

**Table 9.—U.S. imports for consumption of tantalum mineral concentrates, by country**

(Thousand pounds and thousand dollars)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Gross weight | Value | Gross weight | Value |
| Australia | 371 | 4,799 | 150 | 2,032 |
| Belgium-Luxembourg[1] | 21 | 81 | -- | -- |
| Brazil | 351 | 3,895 | 231 | 2,262 |
| Canada | -- | -- | 233 | 2,553 |
| China | 22 | 203 | -- | -- |
| French Guiana[1] | 3 | 36 | 5 | 70 |
| Germany, Federal Republic of[1] | 205 | 2,291 | -- | -- |
| Guyana[1] | 1 | 14 | -- | -- |
| Malaysia | 341 | 1,354 | -- | -- |
| Mozambique | 16 | 152 | -- | -- |
| Netherlands[1] | 105 | 701 | -- | -- |
| Portugal | 11 | 90 | -- | -- |
| Rwanda | 37 | 753 | -- | -- |
| Singapore[1] | 10 | 122 | -- | -- |
| South Africa, Republic of | 7 | 32 | -- | -- |
| Spain | 71 | 672 | -- | -- |
| Taiwan[1] | 8 | 93 | -- | -- |
| Thailand | 609 | 3,688 | 60 | 502 |
| Venezuela[1] | -- | -- | 1 | 20 |
| Zaire | 11 | 79 | 57 | 748 |
| Total[2] | 2,199 | 19,054 | 737 | 8,187 |

[1] Presumably country of transshipment rather than original source.
[2] Data may not add to totals shown because of independent rounding.

Sources: Bureau of the Census and Bureau of Mines.

## WORLD REVIEW

World production data on columbium and tantalum minerals exclude columbium or tantalum recovered from contemporary and old tin slags and from struverite. Tantalum contained in tin slags produced in 1981, 1982, 1983, 1984, and 1985 was, in thousand pounds, 1,006, 991, 1,049, 828, and 877, respectively, according to data from the Tantalum International Study Center.

Regarding the shipments of old tin slags, data continued to be available only from Thailand. Shipments of old tin slags from Thailand in 1985 declined significantly to 22 short tons from 326 tons in 1984. Data were not available as to the disposition of the shipments.

Developments having potential effects on tantalum supply included the International Tin Council's (ITC) announcement on October 24 that the council could no longer continue its tin price support operations owing to lack of funds. The announcement precipitated immediate suspension of trading on world tin markets, including the London Metal Exchange (LME) and the Kuala Lumpur Tin Market (KLTM). Tin trading on the LME and KLTM remained suspended throughout the year. In Thailand, the Government announced new regulations aimed at curtailing tin smuggling activities. The regulations include a ban on transporting tin at night; trucks and boats transporting tin must display identification of the cargo; and tin storage sheds must have concrete walls and floors to resist break-ins. Also, at midyear, the Government reportedly approved a 50% reduction in the Thai tin miner's share of the country's contributions to the ITC.

**Australia.**—For the fiscal year (FY) ending June 30, 1985, Greenbushes reported that throughput and production of tin and tantalum from soft-rock reserves exceeded budgeted estimates. Ore treated was 2.1 million tons in FY 1985, compared with 1.7 million tons in FY 1984. Tantalum oxide produced in concentrates increased to 136,800 pounds from 105,200 pounds in FY 1984. The chemical plant, which operated on one shift thoughout the year, produced 40,100 pounds of $Ta_2O_5$ and 4,400 pounds of $Cb_2O_5$ in FY 1985. Tantalum oxide contained in tantalum glass production was 74,100 pounds in FY 1985, compared with 48,500 pounds in FY 1984, with the tin smelter operating at about 50% of available capacity. The tailings retreatment plant remained inactive, but construction was under way to reestablish the plant with an annual throughput capacity of 1.6 million tons of tailings. Annual production capacity was planned to be 110 tons of tin and about 100,000 pounds of $Ta_2O_5$. The company expected the operation to be its lowest cost tantalite source, with cost of production estimated at less than $20 per pound of $Ta_2O_5$.

Greenbushes completed construction of the primary crushing station for its hardrock project, which was commissioned using spodumene ore. Installed ore capacity exceeds 1.1 million tons per year. However, the secondary crushing and concentrating sections of the project were deferred until June 1986. When they are completed, initial ore production capacity is envisioned at 330,000 tons of ore annually, producing about 220,000 pounds of $Ta_2O_5$ and 310 tons of tin.

Developments reflecting Greenbushes' long-term view of its role in the tantalum market included the start of production of tantalum carbide in the United States under a conversion agreement with Metallurgical Technologies Inc., Houston, TX. Greenbushes was also converting tantalite concentrates to potassium tantalum fluoride and metallurgical-grade tantalum powder through tolling arrangements with Métallurgie Hoboken-Overpelt SA in Belgium.

Talmina Trading Co. reportedly started production at its new Finnis River tantalite mine located about 30 miles southwest of Darwin, Northern Territory. Production was planned at about 24,000 pounds of tantalum concentrates per month. Measured ore reserves were estimated at 161,000 tons containing 3.26 pounds of $Ta_2O_5$ per ton of ore.

**Brazil.**—Early in the year, Cia. Brasileira de Metalurgia e Minerçāo announced plans to invest $4.6 million in equipment to start production of columbium metal at its plant in Araxa. Commercial production was envisioned by midyear 1988 at an initial annual capacity of about 100 tons of columbium metal.

Brazil's total production and exports of all columbium products were 19,500 tons and 16,000 tons, respectively, compared with the 1984 totals of 18,200 tons and 14,600 tons, respectively.

**Canada.**—As reported by Teck Corp. for the FY ending September 30, production of columbium oxide at the Niobec Mine at St. Honoré, Quebec, declined 7% to 6.4 million pounds, compared with 6.9 million pounds in 1984. The operation was closed by a strike from October 19 through November 24, 1984. Ore milled was down 9% to 745,724 tons from 819,772 tons in 1984, as the mill operated on the average at 2,382 tons per day, compared with 2,240 tons per day in 1984. Recovery improved to 61.7% from 60% in 1984, with the $Cb_2O_5$ grade of ore declining to 0.70% from 0.71% in 1984. Ore reserves increased at the end of the FY to about 12.1 million tons assaying 0.66% $Cb_2O_5$, compared with 11.8 million tons assaying 0.66% $Cb_2O_5$ in FY 1984.

The Hudson Bay Mining and Smelting Co. Ltd. reported that tantalum mining and milling activity, which ceased at yearend 1982 at the Bernic Lake, Manitoba, operation of Tanco, remained suspended. Sales of tantalum concentrates by Tanco during 1985 were made from existing stockpiles. However, the tantalum mill continued to be used as a pilot plant to produce lithium-containing spodumene concentrates. Based on favorable pilot test results, Tanco started construction of a full-scale spodumene plant at the Bernic Lake site. The plant, estimated to cost $6.4 million, was planned for completion by yearend 1986, to serve the specialty ceramics and glass markets.

**Japan.**—Production of ferrocolumbium rose to 1,182 tons from the 1,136 tons produced in 1984. Columbium ore imported for ferrocolumbium production declined to 2,176 tons, with Canada providing almost 90%, compared with 2,251 tons in 1984. Ferrocolumbium imports increased more than 40% to 3,163 tons compared with 2,260 tons in 1984. The bulk of imports came from Brazil. Tantalum ore imports totaled 244 tons, compared with 303 tons in 1984; over 60% of the imports came from Malaysia.

Toho Titanium Co. Ltd. announced plans to construct a refining plant in Chigasaki, Kanagawa Prefecture, capable of producing 4.4 tons per month of columbium metal. Construction of the plant was scheduled to start in early 1986. When completed, the plant will be used to produce columbium metal for superconducting magnet applications.

Late in the year, an agreement was reached between Fansteel Inc. and V-Tech Corp. to form a joint venture to produce columbium and tantalum products in Japan. Fansteel will hold a 51% interest in the venture, V Tech-Fansteel Inc. Operation of a pilot plant near Mito, Ibaraici Prefecture, was planned to begin by midyear 1986, with a commercial-scale plant following in 1988.[6]

## Table 10.—Columbium and tantalum: World production of mineral concentrates, by country[1]

(Thousand pounds)

| Country[2] | Gross weight[3] | | | | | Columbium content[e] [4] | | | | | Tantalum content[e] [4] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1981 | 1982 | 1983 | 1984[p] | 1985[e] | 1981 | 1982 | 1983 | 1984 | 1985 | 1981 | 1982 | 1983 | 1984 | 1985 |
| Australia: Columbite-tantalite | 582 | 256 | 258 | [r] [e]455 | 410 | 105 | 45 | 45 | 80 | 80 | 205 | 90 | 90 | 155 | 140 |
| Brazil: | | | | | | | | | | | | | | | |
| Columbite-tantalite | 659 | 443 | 582 | 375 | 400 | 138 | 97 | 134 | 86 | 90 | 178 | 130 | 170 | 110 | 116 |
| Pyrochlore | 65,887 | 43,195 | 37,099 | 66,380 | 70,550 | 27,673 | 18,142 | 15,582 | 27,860 | 29,630 | -- | -- | -- | -- | -- |
| Canada:[e] | | | | | | | | | | | | | | | |
| Pyrochlore | 9,040 | 10,500 | [r]6,700 | [r]9,700 | 10,900 | [5]4,224 | 4,730 | 2,770 | 4,380 | 4,900 | -- | -- | -- | -- | -- |
| Tantalite | 640 | 590 | -- | -- | -- | 19 | 18 | -- | -- | -- | [5]188 | 170 | -- | -- | -- |
| Malaysia: Columbite-tantalite | 51 | 18 | 148 | 60 | [5]168 | 8 | 3 | 22 | 9 | 25 | 4 | 2 | 10 | 4 | 12 |
| Mozambique: | | | | | | | | | | | | | | | |
| Microlite | 107 | 65 | 51 | 22 | 22 | NA | NA | NA | NA | NA | 54 | 33 | 25 | 7 | 8 |
| Tantalite | 75 | 48 | 31 | 15 | 15 | NA | NA | NA | NA | NA | 24 | 15 | 10 | 5 | 5 |
| Namibia: Tantalite | 24 | 20 | 6 | 15 | 10 | 6 | 5 | 2 | 4 | 3 | 7 | 6 | 2 | 4 | 3 |
| Nigeria: | | | | | | | | | | | | | | | |
| Columbite | 831 | 397 | 192 | [r] [e]265 | 220 | 363 | 180 | 85 | 120 | 90 | 48 | 24 | 11 | 16 | 13 |
| Tantalite | 4 | 2 | [e]2 | [e]2 | 2 | (6) | (6) | (6) | (6) | (6) | 2 | 1 | 1 | 1 | 1 |
| Portugal: Tantalite | 20 | 13 | 7 | -- | -- | 5 | 4 | 2 | -- | -- | 5 | 4 | 2 | -- | -- |
| Rwanda: Columbite-tantalite | 126 | 137 | 111 | 115 | [5]61 | 33 | 40 | 33 | 34 | 18 | 28 | 30 | 24 | 25 | 13 |
| South Africa, Republic of: | | | | | | | | | | | | | | | |
| Columbite-tantalite | 8 | 22 | 1 | 1 | (6) | 2 | 7 | (6) | (6) | (6) | 2 | 6 | (6) | (6) | (6) |
| Spain: Tantalite | 129 | 118 | 104 | 70 | 70 | NA | NA | NA | NA | NA | [5]36 | [5]31 | [5]33 | [5]21 | 20 |
| Thailand: Columbite-tantalite | 108 | 86 | 1,210 | 1,052 | [5]591 | 18 | 15 | 205 | 180 | 100 | 23 | 20 | 278 | 284 | 160 |
| United States: Columbite-tantalite | (7) | (7) | -- | -- | -- | (7) | (7) | -- | -- | -- | (7) | (7) | -- | -- | -- |
| Zaire: Columbite-tantalite | [r]176 | [r]132 | 112 | 220 | 350 | 48 | 36 | 30 | 60 | 95 | 50 | 37 | 32 | 62 | 100 |
| Zimbabwe: Columbite-tantalite | 99 | 79 | 5 | 130 | [5]88 | 15 | 12 | 1 | 20 | 13 | 35 | 28 | 2 | 45 | 31 |
| Total | [r]78,566 | [r]56,121 | 46,619 | 78,827 | 83,857 | 32,662 | 23,334 | 18,911 | 32,833 | 35,044 | 889 | 627 | 690 | 739 | 622 |

[e] Estimated. [p] Preliminary. [r] Revised. NA Not available.

[1] Excludes columbium- and tantalum-bearing tin ores and slags. Table includes data available through July 1, 1986.

[2] In addition to the countries listed, China, the U.S.S.R., and Zambia also produce, or are believed to produce, columbium and tantalum mineral concentrates, but available information is inadequate to make reliable estimates of output levels.

[3] Data on gross weight generally have been presented as reported in official sources of the respective countries, divided into concentrates of columbite, tantalite, and pyrochlore where information is available to do so, and reported in groups such as columbite and tantalite where it is not.

[4] Unless otherwise specified, data presented for metal content are Bureau of Mines estimates based, in most part, on reported gross weight. Metal content estimates are revised as necessary to reflect changes in gross weight data.

[5] Reported in official country sources.

[6] Less than 1/2 unit.

[7] A small unreported quantity was produced.

**Rwanda.**—Late in the year, the Société Minière du Rwanda (SOMIRWA) reportedly had gone into receivership after declaring a cessation of payments backdated to July. A heavy debt burden, low prices, and currency difficulties were cited as reasons for SOMIRWA's problem. SOMIRWA, owned 49% by the Rwandan Government and 51% by the Belgian Compagnie Geologique et Minière des Ingenieurs et Industriels Belges, has produced about 60 tons of tantalite ore annually.

**Thailand.**—Columbite-tantalite production continued to decline and was over 40% lower than in 1984; there was no reported production of struverite, compared with 33 tons produced in 1984.

By midyear, Billiton Thailand Ltd. had closed its offshore tin dredging operation. Billiton indicated that cutbacks in production under the ITC's export quota for Thailand and declining ore reserves had made the operation unprofitable. However, the closure of the offshore operation was not expected to affect production at Billiton's tin smelter, Thailand Smelting and Refining Co. Ltd. (Thaisarco) in Phuket, which secures its tin concentrates from all Thai tin miners. By yearend, proposals by former employees of the company to buy Billiton's facilities and resume offshore dredging activities had been turned down by Thai authorities.

At yearend, Thailand's Mineral Resources Department and Thaisarco were taking steps to establish a tin market in Phuket. Prior to suspension of trading on tin markets in late October, Thaisarco was required to buy local tin concentrates on the basis of the Malaysian KLTM price but sold most of its tin output on the basis of the lower LME price.

In midyear, Thaisarco announced an agreement to supply most of its high-grade tantalum-bearing tin slags to the Thailand Tantalum Industry Corp. Ltd. (TTIC) for use at TTIC's columbium and tantalum extraction facility in Phuket. Shipments reportedly were to begin in July. Thaisarco, with a tin metal capacity of about 42,000 tons annually, formerly exported all of its tin slag production, and two U.S. firms, Cabot and Fansteel, were major recipients.

The TTIC completed construction of the chemical plant phase of its columbium and tantalum extraction facility, with commercial production planned by yearend 1986. Reports indicate that the plant will have an initial annual capacity to produce in excess of 300 tons each of $Cb_2O_5$ and $Ta_2O_5$, and over 500 tons of potassium tantalum fluoride.

The Thai Pioneer Enterprise Co. Ltd. (TPE) reportedly was seeking $5.5 million in financing to reopen its tin smelter, which had been closed since midyear 1982. The smelter, with an annual tin metal capacity of about 4,000 tons, also had produced tantalum-bearing tin slags. Also, the Thai Government reportedly granted TPE an exemption from the 4.4% tax normally applied to tin metal exports.

Early in the year, the Thai Ministry of Science, Technology and Energy reportedly signed a $1.78 million technology transfer agreement with Japan's Metal Mining Agency. Under the terms of the agreement, Japan will provide the expertise needed to develop a technique to separate and extract columbium, tantalum, and other rare metals contained in waste derived from milling tin ores in Thailand.

**Zaire.**—Commercial-scale production of pyrochlore from the Lueshe carbonatite deposit reportedly was planned by yearend 1986. Production had been delayed awaiting decision on the choice of power for the new operation. A 1984 study had suggested two power alternatives, a linkup with the existing Bukavu-Goma powerline or the construction of a new powerplant at Kwindi.

## TECHNOLOGY

The Bureau of Mines working with the Defense Reutilization and Marketing Service (DRMS) developed identification and separation techniques for recovery of tantalum from electronic scrap. The joint effort enabled DRMS to sell 200 pounds of discarded tantalum capacitors for $12.61 per pound. All U.S. Department of Defense scrapyard personnel handling electronic scrap were to be trained to perform the separation.

The Bureau of Mines studied columbium and tantalum occurrences in Alaska. This study is to serve as a basis for possible future field and laboratory research.[9] Where columbium and tantalum concentrations are relatively high, these minerals may be recoverable as byproducts of tin, tungsten, gold, or uranium mining. Approximately 135,000 pounds of $Cb_2O_5$ are inferred from the tin- and gold-bearing Tofty placer deposits in the Manley Hot Springs District.

A general trend in the chemical industry is to increase operating temperatures and pressures, requiring stronger materials with better corrosion resistance. Additions of 1% to 3% molybdenum to tantalum reportedly had a pronounced effect on decreasing the susceptibility of pure tantalum to hydrogen embrittlement in severe corrosion conditions. Also, the corrosion rate of tantalum is decreased significantly by the molybdenum additions, while mechanical properties such as strength and room temperature workability are improved.[10]

A process of leaching columbium oxide from pyrochlore concentrate using hydrofluoric acid was described in results from a study initiated by the Canadian Government.[11] Also, the optimum conditions for extraction of columbium oxide from the leach solution, using either the methyl isobutyl ketone (MIBK) or the tributyl phosphate (TBP) process, were determined. The main work was performed with a pyrochlore concentrate prepared from the St. Honoré carbonatite deposit at the Niobec Mine in Quebec. Investigation showed that the TBP process extracts columbium oxide at a lower acid rate than does the MIBK process, while the MIBK process gives a higher purity product.

The levitation melting technique was employed in examining the refining behavior of columbium.[12] The starting material used for the study was impure columbium in the form of columbium-thermite produced by aluminothermic reduction of columbium oxide. The purity of the levitation-melted columbium is compared to that of columbium produced by the conventional electron beam drip-melting process. The technique's inherent advantages include noncontamination due to its containerless feature, melt homogeneity owing to effective magnetic stirring, and precise temperature and atmospheric control during melting and melt holding.

High-chromium irons are used frequently when abrasion resistance is required. In a brief review, initial results of an investigation of columbium as an alloying element in high-chromium irons were described.[13] Melts were prepared in an induction furnace with superheating to 1,500° C for 5 minutes. Pouring temperatures were 1,430° C to 1,450° C. Results suggest that cast iron with a base composition of 18% chromium, 3% carbon, and the balance iron can have its wear characteristics improved by optimum alloying with up to 3% columbium.

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[1] Physical scientist, Division of Ferrous Metals.

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[3] Avon Products Inc. 1985 Operations Annual Report. 16 pp.

[4] Metals Week. V. 56, No. 24, June 17, 1985, p. 8.

[5] Cabot Corp. 1985 Annual Report. 46 pp.

[6] American Metal Market. Alloys and New Materials. V. 93, No. 106, June 3, 1985, p. 27.

[7] The Penn Central Corp. 1985 Annual Report. 44 pp.

[8] Fansteel Inc. 1985 Annual Report. 24 pp.

[9] Warner, J. D. Critical and Strategic Minerals in Alaska. Tin, Tantalum, and Columbium. BuMines IC 9037, 1985, 19 pp.

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# Copper

## By Janice L. W. Jolly[1]

**By yearend, most U.S. copper mining companies planned, or were implementing, programs to lower production costs in order to regain profitability. International monetary debts and exchange rate problems, chronic oversupply, excess world capacity, competing alternative materials, and generally weak economic activity within some domestic markets and on the international market all contributed to depressed prices for 1985. Although two U.S. firms reported profits from their copper operations, most of the domestic copper mining industry was unprofitable.**

### Table 1.—Salient copper statistics

(Metric tons unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Ore produced thousand metric tons | [r]277,516 | [r]181,826 | [r]177,930 | [r]171,814 | 162,210 |
| Average yield of copper percent | 0.51 | 0.55 | 0.51 | [r]0.58 | 0.62 |
| Primary (new) copper produced: | | | | | |
| From domestic ores, as reported by: | | | | | |
| Mines | 1,538,160 | 1,146,975 | 1,038,098 | [r]1,102,618 | 1,105,758 |
| Value thousands | $2,886,440 | $1,840,856 | $1,751,476 | [r]$1,625,116 | $1,632,483 |
| Smelters | 1,294,962 | 940,547 | 888,130 | [r]989,924 | 941,575 |
| Percent of world total | 16 | 12 | 11 | 12 | 11 |
| Refineries | [r]1,419,189 | [r]1,050,445 | [r]1,028,423 | [r]1,089,584 | 1,003,636 |
| From foreign ores, matte, etc., as reported by refineries | [r]124,828 | [r]176,333 | [r]153,667 | [r]75,016 | 53,529 |
| Total new refined, domestic and foreign | 1,544,017 | 1,226,778 | 1,182,090 | [r]1,164,600 | 1,057,165 |
| Refined copper from scrap (new and old) | [r]482,837 | 467,549 | 401,668 | [r]324,949 | 379,181 |
| Secondary copper recovered from old scrap only | [r]591,805 | 517,726 | 449,478 | [r]460,695 | 502,695 |
| Exports: Refined | 24,397 | 30,558 | 81,397 | 91,414 | 87,987 |
| Imports for consumption: | | | | | |
| Refined | 330,625 | 258,439 | 459,568 | 444,699 | 377,725 |
| Unmanufactured[1] | [r]447,140 | [r]524,830 | [r]675,343 | [r]551,802 | 443,982 |
| Stocks, Dec. 31: Total industry and COMEX: | | | | | |
| Refined | 465,000 | 676,000 | 672,000 | [r]544,000 | 291,000 |
| Blister and materials in solution | 277,000 | 233,000 | 174,000 | [r]245,000 | 146,000 |
| Consumption: | | | | | |
| Refined copper (reported) | 2,025,169 | 1,658,142 | 1,803,931 | [r]2,122,732 | 1,905,634 |
| Apparent consumption, primary and old copper (old scrap only) | [r]2,271,050 | [r]1,761,385 | [r]2,018,739 | [r]2,106,580 | 2,152,648 |
| Price: Weighted average, cathode, cents per pound, producers | 84.21 | 72.80 | 76.53 | 66.85 | 66.97 |
| World: | | | | | |
| Production: | | | | | |
| Mine thousand metric tons | [r]7,777 | [r]7,619 | 7,712 | [p]7,986 | [e]8,114 |
| Smelter do. | [r]8,002 | [r]7,933 | 8,143 | [p]8,344 | [e]8,386 |
| Refineries do. | [r]9,178 | [r]9,022 | 9,230 | [p]9,136 | [e]9,230 |
| Price: London, high-grade, average cents per pound | [2]79.35 | 67.14 | 72.18 | [r]62.45 | 64.27 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Incudes copper content of alloy scrap.

[2] Based on Jan.-Nov. monthly averages.

With the shutdown of several domestic fire-refining plants and higher prices for Chilean ingot prevailing on European markets, copper stocks on the Commodity Exchange of New York (COMEX) became highly sought after by domestic brass mills and foundries. As a result, the refined copper inventories on the COMEX continued to be worked down over much of 1985, reaching the lowest level in 5 years by yearend. World stocks, especially those on the London Metal Exchange (LME), however, rose rapidly at midyear in response to reduced demand.

U.S. import reliance,[2] as a percentage of the apparent consumption of refined copper, was 28% in 1985, the highest rate since 1946, largely as a result of the drawdown of inventories from the COMEX. Apparent consumption of copper by U.S. fabricators was highest early in 1985, but was moderated considerably in the second half of the year. A substantial increase in exports of copper concentrates occurred during the year as a result of a shortage relative to available international smelter capacity and the sale of a significant portion of a domestic mining facility to a Japanese firm. In addition, U.S. exports of scrap increased as a result of weakening domestic sales and more favorably priced markets in Canada, Europe, and the Far East.

Changes in ownership of domestic mines and copper-producing plants continued during the year as companies moved to improve their financial status. The new owners included some foreign firms and employee-based partnerships. Several domestic copper smelters and refineries closed during the year with the result that primary annual copper smelting capacity decreased from 1.54 million metric tons in 1984 to about 1 million tons by yearend 1985. Capacity at operating copper mines, estimated at the beginning of the year to be 1.51 million tons of recoverable copper per year, declined by about 230,000 tons during the year as mines were closed, including the largest domestic mine.

**Domestic Data Coverage.**—Domestic production data for copper are developed by the Bureau of Mines from seven separate, voluntary surveys of U.S. operations. Typical of these surveys is the mine production survey. Of 72 operations to which a survey request was sent in 1985, 85% responded, representing an estimated 93% of the recoverable copper content in the total mine production shown in tables 7, 9, and 10. Production for the remaining 11 companies was estimated using data from other surveys.

**Legislation and Government Programs.**—A group of U.S. Congressmen formed the Congressional Copper Caucus to lobby for the domestic copper industry. The 32 Senators and Representatives pursued legislation during the year to support the copper industry. The group reviewed a whole range of policy options, emphasizing copper's economic and strategic importance.

Several bills that pertained to copper were introduced in the House of Representatives and the Senate during the year. Most were referred to various committees. Some of the more significant were as follows:

H.R. 217, January 3. A bill to return to the 95% copper penny.

H.R. 936, February 4. A bill to amend the Bretton Woods Agreements Act and recommend abolishment of the Compensatory Financing Facility (CFF) of the International Monetary Fund (IMF).

H. Res. 126, and S. Res. 114. Resolutions to abolish the CFF.

H.R. 1520, March 7. National Copper Policy Act of 1985. A bill to negotiate copper production limits among major copper producers.

H.R. 1562, March 19. Textile and Apparel Industry bill with Copper Free Market Restoration Act of 1985 attached. A bill to limit copper production and stabilize foreign copper production.

S. 1670, and H.R. 3410, September 19. A bill to establish a Government-to-Government International Copper Action Commission.

H.R. 2187. Superfund Improvement Act of 1985.

H.R. 2557, June 20. Supplemental appropriations bill with attached Senate amendments pertaining to international loans.

H.R. 3714, November 7. A bill to revitalize the U.S. copper industry by negotiation of agreements to temporarily limit copper production.

S. 351, January 31. The American Copper Production Act of 1985. A bill to impose limits on amounts of certain copper articles that may be imported over a 5-year period.

S. 353, January 31. A bill to increase the duty on imported copper by the amount offsetting the cost of domestic environmental requirements.

S. 627, March 7. National Copper Policy Act of 1985. A bill to set terms for negotiation of production cutbacks by major copper producers of the world.

Two stockpile bills: H.R. 3743, November 13, to adjust stockpile goals, and S. 1155, May 16, to amend the 1979 stockpile act.

Of the various bills described, the textile trade bill, H.R. 1562, was passed by the Congress and vetoed by the President. A call for negotiations with foreign countries to limit their production of copper was contained in H.R. 2577, which was signed into law in December, that provided continuing appropriations for a number of agencies of the Federal Government. As with the message on copper negotiations that was part of the textile trade bill, H.R. 1562, the language in the funding measure called for U.S. trade officials to undertake negotiations with countries producing more than 200,000 metric tons of copper per year. However, the report language of the bill was nonbinding.

Multilateral lending institutions were also subjects of several congressional initiatives, including amendments to the Supplemental Appropriations bill, H.R. 2557. One amendment, section 501, instructed U.S. representatives to the International Bank for Reconstruction and Development (World Bank) and other multilateral lending institutions to vote against proposed loans intended to expand copper production in developing nations while copper is in oversupply on the international market. The other amendment, section 502, enunciated a policy statement against multilateral loans that would result in overproduction of any commodity, including copper. Three criteria were established in section 502 for considering a negative U.S. vote: (1) Analysis indicates that reasonable commercial financing is available; (2) surplus capacity for the industry for production of the commodity would exist over one-half of the project life; and (3) U.S. imports of the commodity are more than 50% of domestic production, where the United States is a substantial producer of such commodities. The CFF used IMF funds to compensate nations that suffered a drop in export earnings because of low commodity prices. The sponsors of the bill contended that by allowing the IMF to offer low-interest loans and compensation payments to copper producers in the developing nations, the U.S. Government was indirectly undermining the domestic industry because foreign overproduction of copper was considered a prime reason for low prices and U.S. companies' losses. Between 1979 and 1983, the CFF provided about $1.35 billion per year in subsidies to developing countries, according to one study.[3] CFF supporters described these loans as cushions, helping a commodity-dependent country get through poor economic periods. Opponents described these loans as crutches, allowing countries to keep producing regardless of the impact on prices.

Other legislative proposals were under consideration that would affect U.S. trade, such as H.R. 2451, which would permit the imposition of countervailing duties on imports benefiting from upstream subsidies of raw materials from which the products are made. Congress was also seeking changes in the U.S. Trade Act of 1974 that would take away Presidential discretion in such areas as section 201. Section 201, commonly known as the escape clause, provides for temporary relief for a domestic industry that has suffered or been threatened with serious injury from imports. Trade bills calling for 25% surcharges on imports from Brazil, Japan, the Republic of Korea, and Taiwan were introduced. The bills presented a complicated formula aimed at focusing on countries that maintain trade surpluses by using a variety of unfair barriers against imports.

On September 30, Public Law 96-510, the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund), expired. In December, the House of Representatives passed a tax bill (H.R. 2817) to extend the Superfund, which included taxation of certain copper chemicals, including cupric oxide, cupric sulfate, and cuprous oxide. The proposed tax for these chemicals was about $6.90 per ton. The Senate voted in September to expand the Superfund toxic waste cleanup program nearly fivefold and levy a new tax on manufactured goods to pay for it. Called the Superfund Improvement Act of 1985, it would reauthorize the 5-year-old Superfund law through 1990 and provide $7.5 billion to clean up the worst of the Nation's toxic dumps.

Nine western members of Congress persuaded the Administration to negotiate an agreement with the Mexican Government to prevent a new Mexican copper smelter from opening without pollution controls. An agreement was reached spelling out expectations for environmental controls. The Mexican Nacozari and Cananea smelters were expected to operate in 1986 without environmental control for the near future because of a lack of funds to build sulfuric acid facilities.

A group of domestic producers requested the Administration to consider the benefits of supporting a Producer/Consumer Forum Group that could be patterned after the International Lead and Zinc Study Group. This forum would meet regularly to collect and discuss current monthly copper statistics, develop quantitative information on end uses, provide details of existing capacities, and provide for discussions among representatives of industry and of member governments concerning the problems and opportunities of the copper industry.

In a letter to the Congress in November 1985, the President replied to a congressional request, which was made last year, that the Administration would not try to negotiate voluntary production restraints with major copper-producing nations. The President's letter stated that such negotiations would be inconsistent with the Administration's market-oriented trade and economic policy objectives, and that voluntary production restraints would raise serious antitrust concerns, be too costly to the U.S. consumer, and be too hard to implement. In lieu of these measures, the Administration offered to provide relief to the copper industry through the U.S. Department of Labor, which had begun to implement a plan to assist workers displaced from the copper industry.

On July 8, the President approved the National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict that would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, copper would be categorized in tier II, and the goal would be 26,353 tons, considerably reduced from the previous goal of nearly 1 million tons. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

In an effort to aid the State's depressed copper industry, legislation was passed by the State of New Mexico at midyear to lower New Mexico's excise tax on copper processing by about two-thirds, beginning July 1. The tax on copper processors will be cut to 0.25% from the former 0.75% for 3 years, until July 1988.[4]

## DOMESTIC PRODUCTION

**Mine Production.**—Copper was produced in 12 States during 1985, with Arizona comprising 72% of the total, and New Mexico and Utah in second and third place, respectively. The number of copper-producing mines dropped considerably from 115 mines in 1982 to a total of 68 mines in 1985. In 1985, there were 27 producing copper mines and 41 mines from which copper was produced as a byproduct of gold, lead, silver, or zinc. Total U.S. operating mine capacity, in terms of recoverable copper per year, was estimated to be 1.51 million tons, with 22 major producers accounting for more than 1.45 million tons. Several operating mines closed during the year affecting about 230,000 tons of operating capacity; these included the largest mine in the United States, Kennecott's Bingham Canyon pit in Utah, and Anamax Mining Co.'s Twin Buttes, AZ, electrowinning operation. At the same time, however, some new or reactivated mine capacity was added. The White Pine Mine in Michigan began production late in the year, with a capacity of 73,000 tons per year, and some new or renewed capacity was added at the Morenci, Pima, Ray, and Tyrone Mines. The net result was a mine production that was slightly higher than in 1984. Capacity utilization at active mines was 73% in 1985.

About 3% of total U.S. production of gold and 25% of total silver production was derived as a byproduct of copper mining. By comparison, copper mines had produced about 42% of U.S. gold production in 1979. The estimated value for recovered gold and silver from copper ores was $82.8 million, down significantly from that of 1984. The proportion of copper ore extracted by open pit mining was 88%, compared with 12% extracted by underground methods.

The average cash cost (including byproduct credits and taxes, but excluding depreciation) was further reduced to 58 cents per pound in 1985, from 79 cents per pound in 1981 and 65 cents per pound in 1984, according to Bureau of Mines estimates. When recovery of capital is included, the production cost per pound was 70 cents in 1985. While most copper-producing companies took some losses during the year, two companies, Phelps Dodge Corp. and Cyprus Minerals Co., reported a profit from their copper mines. By comparison, the average cost to produce (with byproduct credits, depreciation, and taxes included) for 110 major international copper mine producers was 67 cents per pound in 1985, including milling, smelting, refining, and transportation charges.

Productivity in terms of tons of copper produced per average hour worked at copper mines and smelters also improved during the year. The average number of copper mine and mill workers, including office workers, for 1985 was 9,854, who worked a total of 18,831,046 employee-hours. For 1984, the comparable numbers were 12,461 workers and 22,587,340 hours. U.S. Department of Labor statistics indicated employment at copper smelters and refineries for 1985 was an average of 5,900 workers; this compared with 8,600 smelter and refinery employees for 1984 and 10,100 workers for 1983. Productivity in terms of employee-hours per ton of copper produced at mines increased from 27.4 hours per ton in 1983, to 20.7 hours per ton in 1984, to 17.0 hours per ton in 1985.

The U.S. Department of Labor awarded the State of Utah a grant for about $2.6 million to aid unemployed miners. The grant was awarded under the Job Training Partnership Act and was part of a title III grant fund that was established to aid dislocated copper and steel workers in 24 States.

In an attempt to reduce costs and improve productivity, AMAX Inc. eliminated 1,500 positions, including headquarters and operating personnel. Reductions were made at the corporate headquarters in Greenwich, CT, at its Golden, CO, offices, and at its domestic and overseas energy and mining divisions. AMAX's losses for 1985 were reported as $621 million, compared with $238.3 million in 1984.[5]

Atlantic Richfield Co.'s subsidiary, Anaconda Minerals Co., continued to sell off its mineral holdings during the year, both in the United States and abroad. Anaconda Minerals sold the idled Montana mining properties at Butte to Washington Corp., a Missoula, MT-based construction company. Montana Resources Co., a subsidiary of Washington Corp., planned to open the mine if sufficient cuts could be made in energy, labor, tax, and other costs. At the time of the shutdown, Anaconda Minerals had estimated production costs at about $1.25 per pound. Washington Corp. estimated the major predeterminable mining costs as follows: 27% for freight and smelting; 15% for employee wages and benefits; 12% for energy; and 7% for taxes.[6] Negotiations for concentrate contracts were being held with 18 different smelters and traders in Asia, Europe, and North America.

In addition, Anaconda Minerals' Carr Fork, UT, property was sold to Kennecott and the mill facilities at Carr Fork to Ok Tedi Mining Ltd. of Papua New Guinea. The company's Los Pelambres deposit in northern Chile was sold to Antofagasta Holdings Ltd. near yearend. A group of investors formed Buffalo Brass Co. Inc. to buy Anaconda Industries' American Brass Div. plants and then announced the sale of two of the plants in Connecticut to another investor group, Valley Brass Corp. Buffalo Brass was to continue to operate plants in Buffalo, NY, Kenosha, WI, and Franklin, KY. Buffalo Brass's Paramount, CA, brass mill was purchased by Cerro Metal Products Corp.

Anamax closed its Twin Buttes Mine in October 1985, laying off most of the company's 156 employees. Jointly owned by AMAX and Anaconda Minerals, Twin Buttes ceased copper mining in 1983, but continued operating a small copper oxide and solvent extraction-electrowinning (SX-EW) plant from existing oxide ore stockpiles. The operation, about 20 miles south of Tucson, AZ, had been for sale, and much of the equipment had already been sold. At its peak in the mid-1970's, the Twin Buttes Mine employed about 2,100 people.

Anamax began reclamation work at the Twin Buttes minesite. The entire tailings area covers about 1,400 acres, containing about 160 million tons of tailings. The company planned to cover the tailings with 6 to 12 inches of alluvium, taking about 15 months to complete the work. Terracing and revegetation were conducted along with mining since 1969, so revegetation is essentially complete. Although the pumps in the open pit mine were shut off in late 1985, the pit water was not expected to become more than 400 to 500 feet deep, taking decades to reach that depth.

ASARCO Incorporated experienced a net

loss after taxes of $62 million in 1985, down from a loss of $306 million experienced in 1984.[7] As part of its strategy to reduce costs, Asarco increased ore reserves at its Mission complex by acquiring the Pima Mine for $12.5 million in September. Pima was owned 75% by Cyprus Minerals and 25% by Utah International Inc. The Pima Mine, which had been shut since 1982, occupied one end of a continuous open pit that was shared by Asarco's Mission complex. Acquisition of Pima permitted control of the entire pit and more efficient mining and milling operations at Mission. All ores from the complex, including the Eisenhower, Mission, Pima, and San Xavier Mines, were to be processed through the Mission mill. According to the company's annual report, 8.9 million tons of ore was milled in 1985, containing 53,500 tons of copper. Ore reserves at the Mission complex were estimated to be 259.8 million tons containing 0.12 ounce of silver per ton and 0.62% copper. At Asarco's Silver Bell Mine, ore reserves were estimated at 19 million tons containing 0.07 ounce of silver per ton and 0.68% copper. No ore was milled during 1985; the entire production of 3,900 tons of precipitate copper was produced through leaching of the oxide ores.[8]

Asarco also operated several coproduct mines that produce copper in Idaho and Montana. In Idaho, Asarco operated the Coeur and Galena Mines. The Troy Mine in Montana was considered a silver mine with a large copper production. In 1985, because of the depressed silver price, the value of copper production exceeded that of silver. About 2.5 million tons of ore containing 3.6 million ounces of silver and 15,240 tons of copper was mined at Troy in 1985. At Coeur, 137,000 tons of ore was milled containing 2.6 million ounces of silver and 1,089 tons of copper. About 180,000 tons was milled at Galena with a production of 1,090 tons of copper and 4.1 million ounces of silver. Ore reserves were given as follows: Coeur, 806,000 tons with 18.74 ounces of silver per ton and 0.94% copper; Galena, 984,000 tons with 15.58 ounces of silver per ton, 0.63% copper, 10.04% lead, and 0.11% zinc; and at Troy, 37.5 million tons of ore containing 1.40 ounces of silver per ton and 0.75% copper.[9] Copper was expected to be a very minor byproduct in the West Fork, MO, mine, which started up in September 1985 and was reported to have reserves of 14 million tons of ore with a content of 0.27 ounce of silver per ton, 5.50% lead, 1.20% zinc, and 0.04% copper.

Environmental studies were continued during 1985 at Asarco's Rock Creek copper-silver project in the Cabinet Mountains Wilderness Area of northwestern Montana. These studies, based on proposed underground mining with access outside the wilderness, were being done as part of the required Environmental Impact Statement and subsequent operating permit applications. An operating plan for the Rock Creek copper-silver mine in the Cabinet Mountains Wilderness Area was submitted to the U.S. Forest Service by Asarco in 1984. The permitting process was expected to take a minimum of 2 years. The Rock Creek ore body lies in the same formation as the company's Troy Mine, which is 15 miles away. The Rock Creek deposit is larger and has a higher ore grade than the Troy deposit.

Echo Bay Mining Ltd. of Edmonton, Canada, completed the sale in late 1985 of Copper Range Co. to Northern Copper Co., a newly formed company comprised 70% of the United Steelworkers of America (USWA) union and mine employees and 30% of Mine Management Resources Inc. Northern Copper paid $23.7 million for the mine and smelter facilities. Financial assistance was obtained from the State of Michigan, Philipp Brothers Inc., and commercial banks. Northern Copper was formed as a vehicle to buy the mine, but the company then merged to officially become Copper Range Co., the name with which it has been historically identified. The White Pine Mine was reopened on November 25, 1985, with 227 workers and at 40% of capacity. The mine was capable of producing 60,000 tons of copper and 1.3 million ounces of silver per year. The mine reportedly had 39 years of ore reserves at this production rate. The miners, represented by the USWA, accepted wages averaging $3 per hour below the average for the industry. Wages were $8.50 per hour, plus profit-sharing and productivity pay. The USWA, representing the workers, agreed to a new 5-year labor contract. The workers were to receive stock in return for wage and benefit concessions. By yearend, the mining complex employed 587 workers, increasing to 900 when the site is at full operation. The smelter was not expected to be fired-up until mine production had reached 15,000 tons of ore per day.

In January, Standard Oil Co. (Indiana) announced plans to spin off its Amoco Minerals Co. into a separate company called Cyprus Minerals. The Amoco spinoff, which was done in the form of tax-free distribution of shares, was accomplished in July 1985. The newly spun-off Cyprus Minerals sustained a loss of $452.1 million for 1985, owing principally to a write-down of some assets. Cyprus Minerals wrote down $195 million of the $385 million valuation of the Bagdad Mine. The Cyprus Bagdad Copper Co. mine, however, was profitable for the year. Cyprus Minerals was selling mining and milling equipment from its Cyprus Pima Mining Co. and Cyprus Johnson Copper Co. operations in Arizona. Pima's reserves were sold during the year to Asarco, but Johnson was to keep producing electrowon cathode from leach dumps through 1986, but at a lower level.

The Wisconsin State Department of Natural Resources was in the process of completing its environmental impact statement on the proposed Exxon Minerals Co. Crandon Mine project. The company expected to start construction in 1987, following approval of permits; production could start about 3 to 4 years later.[10] The deposit had 68.7 million tons of ore that contained about 5.2% zinc and 1.2% copper and minor gold, lead, and silver. Exxon made the discovery northeast of Mole Lake in 1974 and has spent about $75 million on mining preparation since that time.

Echo Bay concluded its agreement with Standard Metals Corp. of New York to acquire the shut Sunnyside gold, silver, and copper mine and mill complex near Silverton, CO, for $20 million plus 30% net profits royalty payable to Standard Metals. Echo Bay planned to refurbish the complex and restart operations in mid-1986 under the name Sunnyside Gold Corp. In 1983, the last full year of production, the mine produced 300,000 tons of ore containing copper, lead, silver, and zinc, in addition to its main product, gold.

Sunshine Mining Co. obtained an option to buy the Gold Fields Mining Corp.'s St. Cloud Mine in New Mexico and was to make a feasibility study to determine ore reserves during the option period, which was to end June 1, 1986. Gold Fields was to operate the mine during the option period at a reduced level of 1,840 tons of ore per month. Ore reserves had been estimated to be 366,598 tons averaging 5.93 ounces of silver, 1% lead, 0.85% copper, 0.3% zinc, and 0.04 ounce of gold per ton. The property had been valued at $1.2 million by Gold Fields.[11]

By various improvements, Inspiration Consolidated Copper Co. (ICC) increased copper production at its mines to 70,000 tons in 1985.[12] ICC's gross copper revenues in the United States and Canada rose from $233.6 million in 1984 to $258.6 million in 1985. Even so, the company's net losses were larger, losing $8.7 million in 1985, compared with $5 million in 1984. By comparison, ICC's parent company, Inspiration Resources Corp., had a net loss of $291.4 million in 1985, compared with a $101.3 million net loss in 1984 and an $82.7 million loss in 1983.[13] While production costs were significantly reduced at ICC, exploration (mostly precious metals) and development expenses increased. Reserves at Inspiration Resources' open pit at Miami, AZ, were estimated to be 240 million tons with 0.53% copper, according to the company annual report. In further cost-cutting moves, ICC was expected to direct increased attention to the more cost-effective dump leaching-SX-EW operation, where the cost of producing copper was about 30 cents per pound. The company determined that it had sufficient oxide and leachable sulfide in the Live Oak-Bluebird-Red Hill area to operate the electrowinning circuit and reduce the mining operations by 40% until economic conditions improve. Inspiration Resources spent $3.2 million in 1985 for the integration of Bluebird Mine into its other operations.

The Southern Pacific Railroad filed an application with the Interstate Commerce Commission to abandon the only rail line that supplies rail service to Inspiration Resources' operation at Miami, AZ. Inspiration Resources protested the abandonment, and a Commission judgement was to be made sometime in April 1986.

The Standard Oil Co. of Ohio (Sohio), parent company of Kennecott, reported a drop in net income for 1985 to $308 million, compared with $1.49 billion in 1984. Sohio's 1985 special charges related to the decision to spend $400 million to modernize Kennecott's Utah Copper Div. Sohio's metal mining operations, principally Kennecott, lost $165 million, compared with $160 million in 1984.[14] Kennecott shut down its Utah Copper Div. in Salt Lake City, UT, on March 31, laying off about 2,200 employees. A care-and-maintenance work force of about 250 employees was retained. The Bingham Canyon Mine had been operating at slightly below one-third of capacity. The company had processed all of its material by the end of June. Kennecott speculated that the expected physical improvements, and labor cost reductions that it hoped to negotiate in 1986, would allow it to cut costs by more than 20 cents per pound.[15] Anaconda's Carr Fork, UT, copper mine was sold to Kennecott. The purchase was to solve boundary line problems and facilitate any future underground mining of the North Ore Shoot, which is contiguous with Carr Fork's reserves. Carr Fork was reported to contain 91 million tons averaging 1.87% copper, 0.02% molybdenum, and 0.27 ounce of silver per ton.

The closure of the Bingham Canyon Mine allowed the associated 5,000-acre tailings pond to dry out, increasing dust complaints. Kennecott planned to increase the discharge of water over the pond and to spend up to $6 million per year on dust control, compared with $2.5 million spent while the mine was operating.

The Nevada State Division of Environmental Protection issued a fugitive dust citation to Kennecott in early November. The company outlined a plan at yearend to the agency to keep dust levels down from the tailings remaining from its closed mine at Ely. Under Kennecott's plan, permanent water-spraying devices would be placed around the dry areas so water could be pumped across it all year. Another part of the plan calls for fertilizer to be spread to maintain plant growth.

Under pressure to operate profitably, Kennecott's Ray Mines Div. laid off 24 workers in May 1985, reducing the total work force to 667. In addition, the operations were monitored monthly after the Utah Copper Div. shut down in late March, and ten, 170-ton trucks were returned to Ray Mines from Utah. The SX-EW plant at Ray Mines was reactivated in December, after being shut since May 1982. The SX-EW plant treats copper-bearing silicate material that cannot be processed through the sulfide concentrator. The ore is crushed and heap leached in vats. Kennecott was selling its production from both Ray Mines and Chino Mines, since its principal refining and rod-mill facilities were closed. Some Ray Mines concentrates were treated at Asarco's smelter in El Paso on a toll basis, with anodes delivered to Phelps Dodge's refinery nearby. Concentrates smelted at Hayden were bought by Asarco.

Chino Mines Co., a two-thirds Kennecott, one-third Mitsubishi Metal Corp. partnership, instituted a radio-computer control system to further lower unit costs at the company's open pit. On August 13, a radial arm stacker attached to and supporting the coarse ore conveyor collapsed, shutting the Chino concentrator down until late September.

Newmont Mining Corp. reported a net loss of $34.2 million for 1985 compared with a net income of $42.3 million for 1984. The 1985 loss included $68 million in special pretax charges, primarily a $40.3 million write-down of Magma Copper Co.'s Superior Mine and a $24.7 million pretax charge for the write-down of Newmont's 40.2% holding in O'okiep Copper Co. Ltd. in the Republic of South Africa. Newmont's subsidiary, Magma, lost $54.1 million before taxes, compared with losses of $44.1 million and $53.3 million in 1984 and 1983, respectively. The resumption of development at the San Manuel Mine had a negative impact on 1985 results, despite stringent cost-cutting measures adopted during 1984. Losses declined at Newmont's Pinto Valley Copper Corp. where the open pit mine and mill operated at full production in 1985, compared with only 8 months in 1984.[16] Newmont Mining reorganized its operations in late 1985, consolidating the management under four group executives. The company's nonferrous metals operations now included the Magma and Pinto Valley subsidiaries in Arizona as well as the Newmont operations in Canada, Peru, and the Republic of South Africa.

In December, Magma took a $40.3 million loss for the labor-intensive Superior Mine and planned to close it if unable to sell or lease it; the operation had been on standby since August 1982. The mine contained ore grading 4.5% copper and had produced about 39,000 tons of copper per year.

Newmont's operating objectives for Magma included cost reductions in four principal areas: (1) lower labor costs; (2) production of ore leach copper; (3) improved mining methods, and (4) higher grade mining plans. Ore reserves at San Manuel were expected to be exhausted in 1993 and the additional reserves available at Kalamazoo would require about $60 million in development costs. A lower cost, mechanized mining system was being developed in the Kalamazoo ore. Magma renegotiated coal, gas, utility, and other supply contracts, withheld pay increases for salaried personnel, and restructured the organization by eliminating or combining jobs. The cost per pound for producing copper at the underground mine at San Manuel remained higher in 1985 than the selling price for copper. The cost of labor was reported to account for just over 50% of the production cost[17] in 1985. Between 1974 and 1985, the average producers' copper price per pound declined from 77 cents to 67 cents, while the average wage at Magma rose from $5.58 per hour to

$13.54 per hour.

Magma announced in March that it would invest an estimated $71 million to develop an open pit mine in the oxide ore deposit that overlies its San Manuel Mine, construct a heap leach pile and build a SX-EW plant. The new plant, with a rated capacity of about 23,000 tons of electrolytic-grade copper per year, was scheduled to begin production by mid-1986. The company was also studying the possibility of developing an in situ leaching operation on another, much larger underground oxide ore body. The new open pit oxide mine was to be in the subsidence area created by the block-caving methods used for mining the first portion of the San Manuel sulfide ore body. Magma indicated that there was between 45 million and 55 million tons of treatable oxide ore available in the new open pit mine, averaging 0.47% acid-soluble copper. No crushing and very little drilling and blasting was expected.

Reserves at San Manuel as of December 31, 1985, were estimated as follows: 51 million tons of oxide ore, containing 0.468% copper; and 270 million tons of sulfide ore containing 0.694% copper, 0.028% molybdenite, 0.029 ounce of silver, and 0.00158 ounce of gold per ton. In the underlying Kalamazoo deposit, 322 million tons of ore was estimated to contain 0.715% copper, 0.28% molybdenite, 0.029 ounce of silver, and 0.0158 ounce of gold per ton. During 1985, about 15.8 million tons of ore was treated at San Manuel, recovering 99,000 tons of copper.[18]

Joining Newmont in 1983, Pinto Valley began shipping copper concentrates to the San Manuel smelter in May 1984, enabling Magma to increase its throughput at the smelter and refinery and thereby reduce unit costs. Magma also has been able to use Pinto Valley's continuous mining machines and experience with mechanized mining methods to good advantage at the San Manuel Mine. There were 607 Pinto Valley employees in 1985, and a 25% reduction in staff positions was made at Pinto Valley during the December 1985 reorganization. At Pinto Valley, the expected mine life was about 11 years, and reserves were estimated at 322 million tons of 0.40% copper and 0.015% molybdenite. About 17.8 million tons of ore was treated during the year with 72,000 tons of copper recovered. All ore grading less than 0.4% copper was leached. Leach solutions at the Pinto Valley Mine were processed by a SX-EW plant adjacent to the mine. A second SX-EW plant was associated with leaching of the old subsidence area of what was once the Miami Copper Co. underground mine. At Miami, leaching solutions percolated through the caved area and were pumped to the surface, producing about 340 tons of electrowon cathode per month. The company was examining the possible in situ leaching of additional oxide ore just north of its Miami underground leach operations to supplement current Miami output. Pinto Valley also owned the Miami East underground mine, which had reserves of about 6 million tons of ore with an average of 3% copper at a depth of about 3,500 feet. Only supply and ventilation shafts and some access drifts had been developed prior to its shutdown in the spring of 1982, shortly before it was scheduled to begin production. The mine was scheduled for flooding and abandonment as soon as equipment is removed.

Phelps Dodge reported earnings from continuing operations of $29.5 million in 1985. Phelps Dodge's mines produced 372,000 tons of copper, according to the company annual report, making it the country's leading copper producer. The company adhered to a rigorous program of reducing operating, personnel, and overhead costs. The copper-producing operations, including mining through copper rod casting, earned $62 million in 1985, compared with a $101.9 million loss in 1984. Phelps Dodge was continuing with the sale of some of its foreign holdings. The assets put up for sale included the company's 10% share in Asian Cables Corp. of India, the 40% interest in Phelps Dodge Philippines Co., and a 53% share in three wire mills in Thailand. Its 44.6% share in Black Mountain Mineral Development Co. (Pty.) Ltd., which operated a copper-lead-silver-zinc mine in the Republic of South Africa, was also to be sold, as was the company's 33% interest in the Woodlawn zinc-copper mine in Australia.

The new SX-EW plant at Tyrone, NM, which was operated by Burro Chief Copper Co., produced over 20,000 tons of copper in 1985, its first full year of operation.[19] The plant started production in April 1984 with costs estimated at below 30 cents per pound. In 1985, the company completed a $15 million program to double the SX-EW plant at Tyrone. The plant began to produce at the expanded rate in December. By 1986, the company expected to produce about 32,000 tons of low-cost copper from this facility. At the Tyrone Mine, an expansion of tailings disposal facilities completed in 1984 enabled the mine to achieve greater production and substantially improved unit costs by moving to a continuous operating schedule. Production was increased and unit costs reduced at both the Morenci, AZ, and Tyrone Mines by increasing the cutoff grade of ore fed to the concentrators and by segregating lower grade material for future treatment by SX-EW. Phelps Dodge's highest cost mine, the Ajo Mine, remained closed throughout the year.

In December, Phelps Dodge announced plans to build a SX-EW facility at the Morenci Mine at a cost of $90 million. The Morenci plant was to produce at an initial rate of 32,000 tons per year, increasing to 41,000 tons about 3 years later. The Tyrone ore body was expected to be mined out no later than the early 1990's, although leach production will continue there for many more years. The Morenci electrowinning facility will replace part of the Tyrone production at significantly lower costs. Further cost improvements were expected to result from the addition of two additional ball mills at Morenci in January 1986, permitting expanded throughput at favorable costs. Perhaps the most significant development was the sale of a 15% undivided interest in the Morenci copper facilities (excluding the closed smelter) to a jointly owned subsidiary of Sumitomo Metal Mining Co. Ltd. and Sumitomo Corp. of Japan for $75 million. Sumitomo was to take a share of Morenci production. The company also expected to sell another 15% interest in Morenci during 1986.

Copper ore reserves at each of Phelps Dodge's U.S. mines and at its Safford, AZ, deposit at yearend 1985 were estimated as follows: Morenci, 722 million tons with an average grade of 0.75% copper; Safford, 238 million tons with an average grade of 0.88% copper; Ajo, 190 million tons with an average grade of 0.50% copper; and Tyrone, 149 million tons with an average grade of 0.80% copper. The company did not visualize reactivating the closed Ajo Mine until the copper price is well above 80 cents per pound.[20] The reserves at Morenci do not include the Western Copper property, purchased in 1981, that adjoins the mine and that was estimated to contain 167 million tons of copper-bearing material containing 0.64% copper, or the low-grade material that will be leached in the proposed SX-EW operation.

After taking a write-down of $100 million for metals assets in connection with the decision to discontinue the metals mining business in 1984, Pennzoil Co.'s board of directors authorized a further write-down of $123 million in 1985 for its metals assets.[21] At yearend, sale of the Sierrita copper deposit had not been finalized, though Cyprus Minerals was expected to purchase the corporation's Arizona copper deposits early in 1986, including the Sierrita Esperanza copper-molybdenum property near Tucson and the Mineral Park copper-molybdenum property near Kingman, AZ. In July, Pennzoil spun off Battle Mountain Gold Co., its former Nevada gold operation, to shareholders.

Duval Corp., Pennzoil's subsidiary, operated Sierrita at full capacity. To cut costs, a 15% wage cut for all employees was started in 1984, two extra shifts per month were added, and the output increased from 85,000 tons to 105,000 tons of ore per day. Employees had been working without a contract since 1983 when Sierrita workers crossed picket lines and voted to decertify their unions. The haulage system at Sierrita had undergone several generations of development, each one an improvement. The shuttered Esperanza Mine mill was restarted in 1984 and linked with Sierrita by conveyor to offset Sierrita's crushing limitations. The portable in-pit crusher had been in operation at Sierrita since 1983, but the mine needed three crushers. In 1985, the operation was close to breaking even at producer prices of 67 cents per pound of copper and $3.75 per pound of molybdenum oxide.[22] Nippon Mining Co. purchased 145,000 tons of copper concentrates from Sierrita in 1985.[23]

The Tennessee Chemical Co. announced in January that it would phase out its copper mining operations near Copperhill in the eastern Tennessee Ducktown copper mining district. Most of the reductions were planned for 1987, but personnel layoffs began in 1985. A total of 900 jobs were expected to be lost. The sulfuric acid plant was expected to stay in operation. The company determined that it was more economical to buy sulfur for the acid plant than to mine the sulfide ore feed. Full production capacity at Copperhill was estimated to be 2.0 million tons of ore per year, from which copper, iron, and zinc sulfide concentrates were separated. Although 60% of the company's sales are from sulfuric acid and liquid sulfur dioxide, copper reportedly accounted for 15% of the sales, with another 15% from copper carbonate and copper sulfate. About 100,000 troy ounces of byproduct silver was recovered per year.

## Table 2.—Production capacity of major U.S. copper mines

(Thousand metric tons, unless otherwise specified)

| State and mine | Company | Status | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arizona: | | | | | | | | | | | | | |
| Bagdad | Cyprus Minerals Co | Operating | 22 | 22 | 68 | 68 | 68 | 68 | 68 | 68 | 78 | 78 | 78 |
| Eisenhower/Paloverde | Anamax Mining Co./ ASARCO Incorporated. | do | -- | -- | -- | -- | -- | 45 | 45 | 45 | 45 | 45 | 45 |
| Esperanza | Duval Corp. | Leach only, 1982 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 6 | 6 | 6 | 6 |
| Inspiration | Inspiration Consolidated Copper Co. | Operating | 45 | 45 | 45 | 45 | 45 | 50 | 70 | 70 | 70 | 70 | 70 |
| Lakeshore | Noranda Lakeshore Mines Inc. | Leach only, 1984 | -- | 20 | 20 | -- | -- | 22 | 22 | 22 | 22 | 10 | 10 |
| Magma/Superior | Newmont Mining Corp | Closed 1982 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | -- | -- | -- |
| Mineral Park | Duval Corp. | Closed 1981 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | -- | -- | -- | -- |
| Mission | ASARCO Incorporated | Operating | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Morenci/Metcalf | Phelps Dodge Corp | do | 150 | 190 | 190 | 190 | 190 | 190 | 190 | 190 | 190 | 215 | 235 |
| New Cornelia (Ajo) | do | Leach only, 1985 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 1 |
| Pima | ASARCO Incorporated | Operating | 80 | 80 | 80 | -- | 80 | 80 | 80 | 80 | -- | -- | -- |
| Pinto Valley | Newmont Mining Corp | do | 70 | 70 | 70 | 70 | 70 | 80 | 85 | 85 | 85 | 85 | 85 |
| Ray | Kennecott | do | 90 | 90 | 90 | 90 | 90 | 90 | 110 | 110 | 100 | 100 | 100 |
| Sacaton | ASARCO Incorporated | Closed 1984 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | -- |
| San Manuel/Kalamazoo | Newmont Mining Corp | Operating | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| San Xavier | ASARCO Incorporated | Closed 1985 | 10 | 10 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| Sierrita | Duval Corp. | Operating | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Silver Bell | ASARCO Incorporated | Leach only, 1985 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 6 |
| Twin Buttes | Anamax Mining Co. | Closed 1985 | 42 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 33 | 33 |
| Total | | | 947 | 1,095 | 1,145 | 1,045 | 1,125 | 1,207 | 1,252 | 1,215 | 1,095 | 1,011 | 943 |
| Michigan: | | | | | | | | | | | | | |
| White Pine | Copper Range Co | Operating | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | -- | -- | 10 |
| Montana: | | | | | | | | | | | | | |
| Arbiter Leach | Washington Corp | Closed 1978 | 15 | 15 | 15 | 15 | -- | -- | -- | -- | -- | -- | -- |
| Berkeley Pit | do | Inactive 1983 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | -- | -- |
| Butte Hill Leach | do | Leach only | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Continental East | do | Closed 1975 | 15 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Kelly | do | do | 10 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total | | | 135 | 110 | 110 | 110 | 95 | 95 | 95 | 95 | 95 | 10 | 10 |
| Nevada: | | | | | | | | | | | | | |
| Ruth | Kennecott | Closed 1978 | 30 | 30 | 30 | 30 | -- | -- | -- | -- | -- | -- | -- |
| Yerrington | Anaconda Minerals Co. | do | 35 | 35 | 35 | 35 | -- | -- | -- | -- | -- | -- | -- |
| Total | | | 65 | 65 | 65 | 65 | -- | -- | -- | -- | -- | -- | -- |

## Table 2.—Production capacity of major U.S. copper mines —Continued

(Thousand metric tons, unless otherwise specified)

| State and mine | Company | Status | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New Mexico: | | | | | | | | | | | | | |
| Chino | Kennecott/Mitsubishi Metal Corp. | Operating | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 110 | 110 | 110 |
| Continental | Sharon Steel Corp | Inactive 1982 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | -- | -- | -- |
| Tyrone | Phelps Dodge Corp | Operating | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 115 | 115 |
| Tyrone Leach (SX-EW) | Burro Chief Copper Co | do | -- | -- | -- | -- | -- | -- | -- | -- | -- | 15 | 25 |
| Total | | | 187 | 187 | 187 | 187 | 187 | 187 | 187 | 187 | 210 | 240 | 250 |
| Tennessee: | | | | | | | | | | | | | |
| Copperhill | Tennessee Chemical Co | Operating | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 10 | 10 | 10 | 10 |
| Utah: | | | | | | | | | | | | | |
| Bingham | Kennecott | Inactive 1985 | 230 | 230 | 230 | 230 | 230 | 230 | 230 | 230 | 230 | 230 | 230 |
| Carr Fork | do | Closed 1981 | -- | -- | -- | -- | 1 | 5 | 14 | -- | -- | -- | -- |
| Total | | | 230 | 230 | 230 | 230 | 231 | 235 | 244 | 230 | 230 | 230 | 230 |
| Total major producers | | | 1,649 | 1,772 | 1,822 | 1,722 | 1,723 | 1,809 | 1,863 | 1,810 | 1,640 | 1,501 | 1,453 |
| Small producers | | | 91 | 74 | 72 | 62 | 47 | 47 | 48 | 41 | 19 | 19 | 17 |
| Byproduct producers | | | 37 | 37 | 36 | 31 | 27 | 28 | 32 | 47 | 45 | 46 | 44 |
| Total all mines | | | 1,777 | 1,883 | 1,930 | 1,815 | 1,797 | 1,884 | 1,943 | 1,898 | 1,704 | 1,566 | 1,514 |
| Number of operating mines: | | | | | | | | | | | | | |
| Copper mines | | | 48 | 46 | 44 | 42 | 40 | 41 | 41 | 36 | 31 | 31 | 27 |
| Byproduct mines | | | 65 | 39 | 48 | 42 | 40 | 38 | 57 | 79 | 74 | 45 | 41 |
| Total | | | 113 | 85 | 92 | 84 | 80 | 79 | 98 | 115 | 105 | 76 | 68 |
| Mill head grade, copper producers (percent copper, weighted average). | | | .65 | .65 | .63 | .62 | .61 | .58 | .61 | .65 | .63 | .68 | .70 |

**Smelter Production.**—Domestic copper smelting from primary and foreign ores continued to contract under the impact of high environmental and energy costs. U.S. smelter production decreased in 1985 compared with that of the previous year, and three primary smelters, which had a combined annual blister production capacity of 364,000 tons, closed by yearend. Eleven primary smelters operated during the year with a total production capacity of 1,384,000 tons of copper. About 208,000 tons of secondary smelter capacity operated during the year at nine plants. Two secondary plants also were closed in 1985.

AMAX began to phase out its U.S. Metals Refining Co.'s copper smelting and refining operations at Carteret, NJ. In recent years, the Carteret facility specialized in processing complex metal scrap and flux for their precious metal content. Although smelting electrolytic refining operations were expected to cease, the company was planning to continue to produce its oxygen-free, high-conductivity copper, retaining 60 employees of the total 700 workers currently employed. The plant had a smelting capacity of 68,000 tons and electrolytic refining capacity of 100,000 tons per year.

Other companies had looked into purchasing the copper smelter at Carteret, but declined because of the environmental problems. U.S. Metals Refining planned to carry out its final smelting and cleanup operations during early 1986. Delays were expected, however, because of concerns voiced by various environmental organizations. The New Jersey Department of Environmental Protection expressed concern about lead emissions at the plant, and the U.S. Environmental Protection Agency (EPA) said the plant was releasing higher levels of dioxin than a dozen other sites in the country. The plant was fined a total of $213,000 by the New Jersey Department of Environmental Protection for pollution violations.

Asarco's copper smelter at Tacoma, WA, was permanently closed in March 1985. Asarco reported 7,530 tons of blister copper produced, compared with 53,000 tons produced in 1984 and 58,100 tons in 1983.[24] The company's El Paso, TX, smelter had a capacity of 104,000 tons of blister copper and produced 77,746 tons of blister in 1985. Blister production of 159,000 tons in 1985 at Asarco's Hayden smelter exceeded its design capacity of 151,400 tons, according to the company's annual report. Asarco cited low copper prices, a shortage of suitable concentrates, and the estimated $150 million cost of meeting Federal, State, and local sulfur dioxide emissions standards as the reasons for closure of Tacoma. The Tacoma plant was one of the few in the world equipped to handle copper-bearing ores that contained substantial amounts of arsenic and had been the largest market economy country producer of arsenic trioxide. The smelter became the focus of national attention in 1983 when EPA proposed standards for limiting the amount of arsenic emitted in the air, including an 82% cutback for Tacoma. The company was looking for a buyer for its associated liquid sulfur dioxide production plant. Asarco's Federated Metals Co.'s secondary plant in Houston, TX, also closed during the year. Asarco's flash smelter at Hayden, AZ, which was completed in November 1983, was capable of processing 54,000 tons of copper concentrates per month and had a concentrate contract with Kennecott's Ray Mines Div. to process up to 25,000 tons per month. In addition, E. I. du Pont de Nemours & Co. Inc. had agreed to purchase 270,000 tons of sulfuric acid per year from the Hayden plant.

Copper Range expected to restart the White Pine smelter and refinery by spring of 1986. Meanwhile, Philipp Brothers was to market White Pine concentrates. The company hoped to produce at least 15,000 tons of ore per day to provide sufficient stockpiles by February 1986 to begin smelter production.

Inspiration Consolidated Copper Co. had smelting contracts with Duval and Cyprus Minerals, which provided about 56% of Inspiration Copper's smelter feed in 1985. The Arizona Department of Health Services (ADHS) brought proceedings against Inspiration for smelter violations. As a result, smelting must be entirely curtailed when the acid plant is not operating. Compliance resulted in reduced smelter production during the second half of 1985. The smelter treated 120,000 tons of Inspiration concentrates and 282,000 tons of toll and purchased concentrates, producing about 120,000 tons of blister copper and 299,000 tons of sulfuric acid during the year.[25]

Smelting was shut down in February at Kennecott's Chino, NM, smelter because of an accident at the acid plant, which caused about $2.5 million in damages to the plant and a production loss estimated at $1.5 million. Mining and milling continued through the monthlong smelter shutdown. Chino also closed the smelter in September for a month to rebrick the furnace following the temporary shutdown of the mill owing to an accident at the mine. The modernized smelter at Chino was started up in October 1984, marking the completion of a $350 million mine, concentrator, and smelter modernization and expansion project that started in 1981 and cut operating costs by about 31 cents per pound. The new Inco flash furnace raised annual smelter capacity to 120,000 tons of copper metal per year. In July, Chino approved installation of a $4.5 million anode furnace and expected to begin production by January 1986. Chino had ceased fire-refining in July 1984.

Kennecott closed its 210,000-ton-per-year smelter at Garfield, UT, in April, following the Bingham Canyon Mine closure. The company was to begin modernization of the associated mining and milling facilities in 1986. The smelter had been converted to a modified Noranda continuous smelting process in 1978 at a cost of about $280 million. The modified smelter captured over 86% of the sulfur, compared with 55% recovery at the old facilities.

Magma was studying the cost and practicality of constructing a new flash smelter to process 2,700 tons of concentrates per day at its San Manuel Mine in Arizona to comply with environmental regulations. It would require an investment of $135 million to retrofit the San Manuel smelter.

Phelps Dodge's Hidalgo, NM, smelter benefited from 1984's $27 million rebuilding and improvement project and smelted a record high 153,300 tons of copper, according to the company's annual report. The corporation determined that it would defer the capital expenditures necessary to bring its smelters at Ajo and Morenci, AZ, into compliance, and consequently, those smelters were closed in December 1984 and April 1985, respectively. Concentrates produced at its mines that exceeded what could be handled by the two operating smelters at Douglas and Hidalgo, AZ, were being sold. A $10 million project was in progress to relocate a relatively new oxygen plant from the Morenci smelter, where production was suspended at the end of 1984, to Hidalgo. The addition of oxygen enrichment at Hidalgo was expected to improve energy and pollution control efficiencies and benefit unit costs there.

**Refinery Production.**—Compared with the 1984 level, production of refined copper from U.S. primary and secondary plants was down in 1985. This was largely the result of decreased production at primary plants. In 1985, 10 electrolytic refineries, 10 electrowinning plants, and 6 fire-refining facilities operated. During the year, however, four of these refineries had closed. At yearend, total U.S. refinery capacity, estimated to be 1,838,300 tons, comprised 1,407,800 tons being utilized for primary metal production and 430,000 tons as secondary capacity.

AMAX closed its Port Nickel refinery in Braithwaite, LA, at the end of November. The remaining 265 employees were laid off. AMAX also began phasing out its secondary copper and precious metals refining operations at Carteret, NJ. Approximately 130,000 tons of copper refining capacity would be withdrawn through the closure of the two AMAX facilities.

According to the company's 1985 annual report, Asarco's Amarillo, TX, copper refinery had a capacity of 414,000 tons of cathode and produced 376,000 tons of copper, compared with 314,000 tons in 1984. The refinery set a new monthly record-high production of 37,345 tons of refined copper in May. The plant was designed to produce 32,000 tons per month, but the increase in electric current efficiency provided by Asarco's patented Reatrol process enabled the capacity to be exceeded. The Amarillo refinery no longer produced wirebar. With completion of a $6 million rod cleaning system in early 1984, the continuous casting copper rod mill at Asarco's Amarillo copper refinery was able to produce up to 50 tons, or about 70 miles, of continuous cast copper rod per hour without interruption. About 820 employees worked at the Texas operation.

Duval closed its 5,000-ton-per-year Battle Mountain, NV, electrowinning plant in 1984, but continued to produce copper precipitates. United Technologies Essex Inc. permanently closed its 34,000-ton-per-year fire-refining facility at Three Rivers, MI, in April 1985, transferring its home-scrap reprocessing activity to a new continuous cast scrap processing operation in Indiana. The fire-refining facility of the Metal Bank of America in Philadelphia, PA, was closed at yearend 1984, as was Chino's fire-refining plant in New Mexico.

According to the Inspiration Resources 1985 annual report, refining copper production from its refinery complex at Miami, AZ, was 70,000 tons in 1985, compared with 77,000 tons in 1984. Sales of refined copper in the United States increased during the year to $164 million from $144.4 million in 1984, as a result of increased concentrate purchases and higher mine production. Inspiration Consolidated Copper finished a renovation of its rod plant in Claypool, AZ, registering increased efficiency and production in 1985.

Kennecott restarted its copper SX-EW plant at Ray Mines Div. in December, which had been shutdown since 1982. The SX-EW plant recovers copper from silicate type ore and can produce about 20,000 tons of high-purity copper per year. In June, Kennecott closed its 195,000-ton-per-year electrolytic refinery at Garfield, UT.

Magma's San Manuel refinery had an annual design capacity of 195,000 tons of electrolytic copper. The associated rod plant had a capacity of 145,000 tons of continuous cast copper rod per year. Gold recovered at the refinery from the San Manuel Mine ore in 1985 amounted to 20,132 troy ounces and sold at an average price of $321.73 per ounce, providing a total revenue of $6.5 million. In addition to gold, the company recovered 384,976 ounces of silver and 85,495 pounds of selenium from San Manuel ore. Byproduct molybdenite, recovered at the mill, brought the company $9.6 million in 1985. Total revenues from metals other than copper from the San Manuel Mine was $2.5 million, which paid for 21% of its $97 million payroll in 1985.[26]

Magma's new SX-EW plant was expected to considerably lower copper production costs at San Manuel when it begins production in mid-1986. The pregnant leach solutions from the leach pads and later, from the in situ deeper level oxide zone, were to be pumped to the SX-EW plant, where at least 85% of the acid-soluble copper available for dump leaching was expected to be recovered at a rate of about 22,000 tons of refined copper annually. The new plant was to use new technology by applying an Australian technique that employs permanent steel cathode starter sheets, and a Magma-patented mechanism for controlling tankhouse fumes. The company expected to spend about $71 million to develop the oxide ore open pit mine, construct the heap leach pads, and build the SX-EW plant. Production costs of less than 55 cents per pound were anticipated. Newmont's Pinto Valley was producing about 12,000 tons of electrowon cathode per year at the Pinto Valley and Miami Mines. The company may also expand the Pinto Valley electrowinning facility. Newmont's MCR Products Co. started shipping copper rod to customers in early April 1985 from its newly acquired 127,000-ton-per-year continuous cast rod plant at Cicero, IL.

A new system of vertical furnace melting and anode casting was installed in 1985 at Phelps Dodge's El Paso, TX, electrolytic refinery plant. Improved technology also was being put in place in the tankhouse to improve productivity, and a $7 million energy cogeneration project was nearing completion, all of which were expected to strengthen the cost-competitive position of this plant. Two modern continuous cast copper rod mills in El Paso, TX, and Norwich, CT, operated at a combined annual capacity of 385,500 tons in 1985. The corporation was increasing the proportion of refined copper sold as rod, and more than 68% of its refined copper sales outside of the corporation was as rod in 1985, compared with only 41% in 1983. The new expansion to the SX-EW plant at Tyrone, NM, started producing cathode on December 1, a month ahead of schedule. Burro Chief Copper was the operating company for the electrowinning operations at Tyrone.

Louisiana Land and Exploration Co. (LL&E) was to lease the White Pine refinery to Copper Range with the option to purchase through 1988. Meanwhile, Copper Range was expecting to be producing blister from the White Pine smelter by the end of April 1986. LL&E wrote down $29.9 million against the value of the electrolytic copper refinery in 1985.

**Copper Sulfate.**[27]—Copper sulfate was produced from copper scrap, blister copper, copper precipitates, electrolytic refinery solutions, and spent electroplating solutions by at least seven companies. Imports, primarily from Canada, Italy, and Peru, accounted for about 8% of domestic consumption during the year. The estimated end-use distribution of shipments from domestic producers was 46% for agricultural uses such as fungicides and fertilizers; 42% for industrial uses such as metal finishing, mineral froth flotation, and wood preservatives; and 12% for water treatment.

Chevron Chemical Co., which produced a small quantity of copper sulfate during 1984, had no production in 1985, and Anaconda Minerals permanently closed its small Twin Buttes, AZ, operation during the last quarter of 1985.

Kocide Chemical Corp., a major producer of copper sulfate, was planning to start up an in situ leaching operation at the old underground Van Dyke Mine at Miami, AZ, to secure a supply of copper precipitates for feedstock at the company's Casa Grande, AZ, copper sulfate plant. Ore reserves at the mine were estimated at 90 million tons of 0.5% copper in oxide ore, and initial precipitate production was planned at 3,000 tons of copper per year.

Table 3.—Copper sulfate producers in the United States in 1985

| Company | Plant location |
|---|---|
| Anaconda Minerals Co | Twin Buttes, AZ. |
| CP Chemicals Inc | Sewaren, NJ, and Sumpter, SC. |
| Kocide Chemical Corp. (formerly International Metals Recycling Corp.). | Casa Grande, AZ. |
| Madison Industries Inc | Old Bridge, NJ. |
| Phelps Dodge Corp | El Paso, TX. |
| Southern California Chemical Co | Santa Fe Springs, CA, Union, IL, Garland, TX.[1] |
| Tennessee Chemical Co | Copperhill, TN. |

[1] Production from these plants is not included in production data.

**Sulfuric Acid Production.**—Sulfuric acid production as a byproduct of copper smelting in the United States was valued at $31.8 million for 1985. Four smelters in Arizona produced 998,000 tons, and six smelters in New Mexico, Tennessee, Texas, Utah, and Washington produced 1.27 million tons of sulfuric acid. Of the total, about 63,500 tons was consumed at the smelters themselves for purposes other than manufacturing acid. Total sulfuric acid produced in 1985 as a byproduct of all copper, lead, and zinc acid smelters and zinc roasters in the United States was 2.9 million tons, valued at $56.3 million.

## CONSUMPTION

Annual demand for copper in the market economy countries was about 7.5 million tons in 1985, which was about 9% higher than the low consumption of 1982. About 82% of the total was consumed in three industrialized regions of Western Europe, Japan, and the United States. The United States comprised about 29% of the total in 1985.

Consumption of copper-mill products in 1985 by U.S. manufacturers was distributed among the end-use sectors and was reported by the Copper Development Association Inc. (CDA)[28] as follows: CDA estimates included electrical product uses distributed among the market sectors, and the end-use allocations are distributed based on gross weight of copper and copper alloy shipments during the year. Consumption of brass mill, wire mill, foundry, and powder mill products was down 7.2% from that of 1984 and was distributed among the following market sectors: construction, 40%; electrical, 23%; machinery, 14%; transportation, 12%; and other (including ordnance), 11%. According to CDA,[29] the top 10 markets in the United States during 1985 were, in order of importance, plumbing, building wire, telecommunications, power utilities, in-plant equipment, air conditioning, automobile electrical, automobile nonelectrical, business electronics, and industrial valves and fittings.

Based on copper content of U.S. apparent consumption of copper, including copper content of all old scrap, and calculated with electrical and electronic uses extracted from all sectors except that used in ordnance, the end-use distribution, according to the Bureau of Mines, was as follows: electrical, 65%; construction, 18%; machinery, 6%; transportation, 5%; ordnance, 2%; and other, 4%. The most significant change in recent years has been the increase in copper consumption relative to other sectors by the electrical and electronic end-use sector, from about 58% of copper consumption in 1979 to about 65% in 1985. This also was reflected in the increased relative percentage of refined copper consumption at wire mills, which in 1979 consumed 69% of reported refined copper consumption and in 1985 consumed 72%.

Recent observations[30] by the International Copper Research Association Inc. (INCRA) indicated a swing away from using copper in communications, internal combustion vehicles, and printed circuit boards. Telecommunications cable was the most threatened product of the copper wire market. While substitution by optical fibers was important, at least five other factors were also a threat: (1) microwave transmission, including satellites; (2) thinner gauge wire; (3) multiplexing; (4) digital systems; and (5) electronic switching. Another source[31] indicated that in 1985, the telecommunications sector experienced a 26% drop from that of the previous 5 years. In 1985, according to INCRA, 80% of all cars made in Western Europe had aluminum radiators, but only 30% of U.S. cars and 4% of Japanese cars.[32] In addition, radiator tank components were being increasingly made of plastics for both copper and aluminum radiators. In 1980, the average U.S. auto contained 34 pounds of copper, distributed one-third for radiators and heaters, one-third for wiring harnesses, and one-third for alloys used in the engine and elsewhere. In 1985, the average automobile weighed 3,100 pounds and used about 31 pounds of copper.[33] Automobile wiring has been increasing, but increased use of microprocessors may slow this growth. Between 1977 and 1983, downsizing, material substitution, and increased engine efficiency accounted for a loss of 15.8% of the copper consumed in this industry on a worldwide basis. Chrysler Corp. announced in 1985 that it would retain copper radiators in its U.S. vehicles.[34] The major usage of copper radiator strip in Europe was in the replacement market and/or heavy vehicles. There was no imminent threat from aluminum in those segments.

Four new market opportunities of significance for copper were also indicated by INCRA's research:[35] heat pumps, solar power, desalination facilities, and electric vehicles. Solar power was a promising area, with passive solar the main area for growth during the next 20 years. Use of copper solar radiator systems in the United States consumed more than 10,000 tons annually and was growing slowly. Large-scale solar electric generation plants were not considered economically favorable. Energy-efficient heat pumps were being used more extensively in heating and cooling buildings. Sales rose from 100,000 units in 1970 to 500,000 units in 1980 in the United States. By 1990, it was expected that over one-third of new homes will be equipped with heat pump facilities and the total market for the United States will exceed 1.0 million units. Desalination and other marine applications accounted for about 100,000 tons of copper alloys per year. The largest applications continued to be ship propellors and condenser tubes for heat exchangers in coastal power generating plants. Desalination plants remained a long-term opportunity for copper. Copper usage was also expected to increase in copper alloy tooling in fabrication of aerospace and automobile advanced composite structures, in power handling systems, in electronically controlled devices used in automated machinery, as power supplies for lasers, and in superconducting devices.

Nuclear canisters were also seen by CDA as a growth market. Spent nuclear fuel will remain radioactive for about 1 million years. The CDA was working on a feasibility study under a $6 million contract with the U.S. Department of Energy to examine the possibilities for the use of copper as nuclear containers. The French were currently using a solid copper canister.[36]

Changes in the U.S. copper alloy and brass mill industry continued during the year. From being the fourth largest basic industry in the United States, the nonferrous foundry industry had decreased considerably in importance over the 3 years ending with 1985. During this time, about 33% of the U.S. casting production was lost to overseas foundries, mostly to foundries in Taiwan. Much lower wages and significant currency devaluations have been largely responsible. The average U.S. foundry worker was paid $350 per week compared with $25 per week in Taiwan. With the possible exception of the highly automated high-production foundries, the U.S. foundry industry has a very serious and continuing problem. Furthermore, what happens to the nonferrous foundries determines what happens to the brass and bronze sales volume of the copper and copper-alloy ingot maker and the volumes of scrap sold to these processors. All experienced drastic decreases in recent years.[37] H. Kramer & Co., a major brass ingot maker, filed for bankruptcy in Chicago. The company's El Segundo, CA, plant was sold to Cerro Metal Products. Among the larger producers, Century Brass Products Co. closed its brass mill in Waterbury, CT, in February 1985. The mill closed after the labor union's rejection of a request for wage and benefit concessions. A group of investors formed Buffalo Brass to buy out Anaconda Industries' American Brass Div. plants. The company then sold two of the Connecticut plants to Valley Brass. Buffalo Brass would continue to operate plants in Buffalo, NY, Kenosha, WI, and Franklin, KY.

## STOCKS

High-grade copper sales, contracts, and inventories and their relationship with commodity exchange copper contracts compared with the demands of the copper marketplace spawned some new market elements. The problem of a large quantity of poor-quality wirebar inventories and other forms deliverable against COMEX and the LME higher grade copper contracts had been perceived for some time as holding down the price of genuine higher grade copper, which was also deliverable to these contracts. With a major proportion of stocks in the LME high-grade, and COMEX copper contracts actually unsuited to the high-grade consumer's needs, a system of off-market premiums evolved for good-quality copper. The price of this copper was depressed to such an extent that the LME standard cathode contract traded at a premium to its higher grade companion for a time in 1984. In addition, the high-grade contract failed at mid-1985 to attract sufficient material into warehouses to prevent backwardation forming; the tightness was exacerbated by the presence in what little stock there was of poor-quality wirebars. The cost of buying these wirebars and reprocessing them to raise their quality was beyond the resources of the producing countries, so this solution was not taken. Eventually, in 1985, the LME decided to opt for a two-contract system—standard and Grade-A. The standard contract was to include all grades, including Grade-A deliverable material. The Grade-A contract would include high-grade cathode plus some select wirebar brands. The new LME two-contract system, with the Grade-A contract deliverable against the standard contract, avoided the need to declare the poor-quality wirebars nondeliverable. Three-month trading of the new Grade-A contract was scheduled to begin on April 1, 1986, with cash trading beginning July 1.

The Midamerica Commodity Exchange in Chicago, IL, submitted recommendations at yearend to the Commodity Futures Trading Commission (CFTC) that would bring that exchange's copper futures contract more in line with the LME. An increase in the contract size from 12,500 pounds to 55,000 pounds of high-grade copper, compatible with LME's higher grade contract, was recommended. It also recommended that both U.S. and European warehouses be registered as delivery points, a move that would give the new contract access to immediate liquidity, as well as making the contract truly arbitrable with Europe. The contract was expected to start in 1986.

COMEX also submitted a proposal to the CFTC for a new high-grade contract plus an amendment to the current contract, increasing the premium for No. 1 electrolytic cathode by 1 cent to 1.5 cents per pound, in an effort to upgrade the exchange's existing contract in keeping with the dominance of high-grade copper in the international marketplace. Only No. 1 electrolytic cathode would be deliverable under the proposed contract, but its size, all delivery points, and trading hours would remain the same as in the current contract. There was a shortage of copper coming into COMEX warehouses, owing to the poor quality of existing COMEX stocks, the lack of new low-grade copper supplies on the market, and the low COMEX contract price.[38] The only available refined copper supplies on the market were high-grade, but COMEX prices would have to increase 3 to 4 cents per pound before high-grade metal will go to COMEX rather than to the consumer. Brokers and dealers were sometimes transacting their own business and writing their own contracts with their own terms rather than working through an exchange broker because of the confusion in the contract terms.

The contraction of COMEX stocks during the past 2 years was attributed to domestic refined copper production cutbacks and steady demand for COMEX material by brass mills. At the end of 1983, COMEX copper inventories stood near a record high of 371,000 tons. By the end of 1984, inventories had receded to 251,000 tons. This dramatic decrease continued through 1985 to 109,000 tons at yearend, the lowest level in almost 5 years. Most of the remaining stocks on COMEX were standard cathode and fire-refined ingot at yearend 1983. As a result, brass mills have constituted the single largest consumer of COMEX inventories over the past 2 years. The standard COMEX grades and shapes were reportedly more energy efficient than No. 1 scrap and were preferred despite the COMEX premium of 3 to 4 cents over the price of No. 1 scrap. In addition, some Chilean ingot bars that previously had been exported to the United States were being shipped to Europe because of slightly higher prices prevailing in continental markets.[39] Primary fire-refined copper ingot from Chino also ceased with the startup of their new anode furnace.

The increase in LME stocks during 1985 was 63,000 tons, but in October was as high as 80,500 tons. Stocks of copper in the LME warehouses fell from 205,600 tons in the first week of October to 184,025 tons in early December, of which 131,825 tons was high-grade cathodes, 48,650 tons was wirebars, and 3,550 tons was standard-grade cathodes. At the beginning of January 1985, LME inventories were 125,075 tons, comprised of 69,950 tons of wirebar, 47,150 tons of high-grade cathode, and 7,975 tons of standard-grade cathode.

In copper, the normal range of inventories was the equivalent of 1 to 1.75 months worth of current consumption, according to some analysts. It was speculated that one aspect of the inventory-price relationship that might be increasingly important, and one that might help to explain some of the metal price weakness since 1983, was the greater role of exchange warehouses as the location of metal inventories. The percentage of total metal stocks held on the exchanges peaked in 1983 compared with those held by producers. High inventories have a more negative effect on prices, the closer those inventories are to the market. The more inventory held by producers, the greater resistance to selling at just any price. Inventory levels might therefore be the most important guide to price trends.[40]

## PRICES

The strength of the U.S. dollar and the seasonal weak demand of domestic semifabricators were two major factors for U.S. copper price weakness through much of 1985. Copper prices on the COMEX improved to about 70 cents per pound in the second quarter in response to the continued drop in refined copper inventories, but remained depressed at about 66 cents per pound from July through November as refined copper stocks accumulated in response to seasonal lower demand. However, the weakening dollar and renewed drawdown of refined copper stocks on the COMEX in September exerted a modest upward influence on U.S. prices by yearend. The COMEX price averaged 63.2 cents in December.

Suspension of trading of tin on the LME in October also temporarily dampened demand and price for copper. The tin crisis broke on October 24, and the nature of trading on all LME rings altered markedly. Between October 24 and October 31, the LME price for copper decreased by up to 5.8% as traders made adjustments for the International Tin Council members who were in default to members of the exchange. However, there was little evidence that trading had become distorted to the extent that LME prices for copper had become seriously divorced from the market fundamentals.

According to some analysts,[41] the changes in exchange rates in recent years have had their largest effect among metals markets on the copper market. The copper-producing nations had the largest devaluations in excess of inflation than producers for other metals. Low copper prices triggered devaluations in those countries where it was a major source of export income. Currency fluctuations were considered a major factor in making some mining and production operations profitable or unprofitable. It was suggested that had the excessive devaluations not occurred, copper prices in U.S. dollars would have been 27% higher in 1984 than was the case. In other words, instead of the LME price of 62 cents per pound, the price would have been about 79 cents per pound. A 79-cent producer-realized price would allow almost all U.S. mines at least to break even and show a small profit. The strength of the dollar seemed to have been the major factor behind the supply-demand fundamentals relationship with price, including lower levels of consumption, higher levels of production, and corresponding changes in inventory that eroded part of the gains in dollar prices.

Market conditions during the past several years brought about some pricing changes by U.S. producers for their cathode and rod in an attempt to address the needs of the consumer. Some producers adopted a flexible premium structure based on COMEX prices, while others regularly adjusted prices to follow the COMEX spot price but were not tied to it. Phelps Dodge has been using a COMEX-based pricing method for its copper rod for more than 2 years. In January 1985, Corporación Nacional del Cobre de Chile (CODELCO-Chile) also switched to this premium pricing method for its cathode sold in the United States. In November, Newmont announced an intention to put into effect its premium pricing system over the COMEX settlement price for its cathode sales beginning in January 1986, breaking a longstanding tradition of producer pricing. Inco Ltd., Kidd Creek Mines Ltd., and Noranda Mining Inc. also had COMEX-related pricing structures. Asarco, Duval, Inspiration Resources, and Phelps Dodge all retained producer cathode price structures.

Phelps Dodge's rod premium was 9.5 cents per pound more than COMEX prices through the end of 1985. Premiums for cathode sold by merchants on the east coast averaged 5 cents per pound over COMEX at yearend; by comparison, premiums were as low as 5 cents when Phelps Dodge first switched to a COMEX-based pricing system on January 1, 1984. Prior to that change, the company had priced its rod on the basis of a 4.85 cents per pound premium over its published cathode price.

No. 2 copper scrap was stable in price throughout 1985 at about 37.50 cents per pound average per month. This compared with an average monthly price for 1984 that in January was 41.17 cents per pound and decreased to 35.67 cents in December. The average price of No. 2 copper scrap during 1984 was 39.81 cents. The average price for red brass solids ended 1985 at 39.5 cents per pound, compared with a January price of 40.50 cents per pound.[42]

Representative prices of brass and bronze ingots, in cents per pound, as quoted by ingot makers, effective June 7, 1985, were as follows: alloy 100 at 91 cents; alloy 110 at 90.25 cents; alloy 193 (88-10-2 group) at 209.50 cents; alloy 327 (80-10-10 group) at 88.25 cents; and alloy 295 at 164.00 cents. In the yellow group, alloy 400 was quoted at 71.25 cents and alloy 409 at 82.25 cents.[43]

## TRADE

The U.S. import reliance for refined copper was at a record high during 1985. As a percentage of apparent consumption of refined copper, the U.S. import reliance reached 28% in 1985; this compared with an import reliance of 1% as recently as 1982. This was attributed to the drawdown of inventories from COMEX in lieu of increased refined imports, which although high, were at a lower level than refined copper imports of 1984. At the same time, domestic exports of copper in scrap and concentrates increased significantly during the year, largely as a result of a slowdown in domestic brass mill and copper smelter activity. A shortage of high-grade copper concentrates relative to available international smelter capacity, and the sale of a significant portion of a domestic copper mining facility to a Japanese firm, resulted in a substantial increase in export of copper ores and concentrates to Canada, Japan, the Republic of Korea, and Taiwan during the year.

The surge in imports over the past 2 years of lower priced copper and copper alloy semimanufactures also was seen as being responsible for the weakening of scrap sales to domestic brass mills. As a result of soft U.S. markets, scrap dealers reportedly turned to Asian, Canadian, and European markets for sales. Scrap exports accordingly jumped by two-thirds, primarily to the more favorably priced markets in Belgium, Canada, the Federal Republic of Germany, Italy, Japan, the Republic of Korea, and Taiwan, where scrap demand by expanding copper semimanufacturing industries had grown.

Imports of brass mill products (copper rod used for electrical wire purposes is not included) fell by 17.6% during 1985 to 216,700 tons, compared with the record high of 263,000 tons imported in 1984. However, the amount imported was still significantly higher than the 182,000 tons imported in 1983. Exports of copper and brass mill products leveled off at near 1984 levels, reaching 30,700 tons during 1985. This was down considerably from the record high of 96,400 tons exported in 1980. Most brass mill product exports went to Canada and Mexico.

CODELCO-Chile USA assumed responsibility from Cerro Sales Corp. as CODELCO-Chile's sales agent in the United States and Canada, effective January 1, 1986. Cerro Sales had been CODELCO-Chile's sales agent in the United States and Canada for 10 years and handled about 125,000 tons per year of CODELCO-Chile's copper. Westinghouse Corp.'s Abingdon continuous cast rod mill's business was shifting from tolling to more direct rod sales and it increased copper purchases from Chile during the year to provide the material for this new direction. CODELCO-Chile was reported as selling 1,500 tons of refined copper per month and Empresa Nacional de Minería (ENAMI) 750 tons per month to Westinghouse, which had an annual capacity of 60,800 tons of continuous cast rod.[44]

Final antidumping duties of 3.3% were to be imposed on imports of low-fuming brazing copper wire and rod from the Republic of South Africa as a result of a ruling by the International Trade Commission at yearend. The unfair trading cases were aimed at subsidiaries of McKechnic Bros. Ltd., a United Kingdom-based firm with operations in both the United Kingdom and the Republic of South Africa, and were filed in February 1985 by American Brass Co., Century Brass, and Cerro Metal Products. The International Trade Commission also found that imports of low-fuming copper brazing rod and wire from New Zealand had caused injury to domestic producers. Importers of New Zealand material will be required to pay a combination of antidumping and countervailing duties equivalent to 26.93% of the product value.

## WORLD REVIEW

World mine production of copper rose by nearly 130,000 tons in 1985, reaching 8.1 million tons; most of that increase was in market economy countries. Australia, Canada, Chile, Papua New Guinea, and Peru accounted for most of the increased production. World refined production also increased marginally. Copper consumption rose at a moderate rate during the first part of 1985, and for a while, industry and terminal market stocks plummeted weekly. For the year, world copper consumption decreased slightly to 9.7 million tons. Market economy country consumption of refined copper decreased during the year owing to cutbacks in Canada, Japan, and some Western European countries. Increased consumption was indicated for Australia, Belgium, Brazil, China, the Republic of Korea, Mexico, Sweden, the United States, and centrally planned economy countries.[45] At yearend, lower oil prices and a further decline in the value of the dollar helped to stimulate consumption in the United States. The strengthening Japanese yen had the opposite effect upon Japan's copper consumption, where imports of refined copper in 1985 were down sharply from those of 1984.

At the beginning of 1985, a slight deficit developed in the market economy countries' balance of copper supply and demand, largely as a result of the strong inventory drawdown that had occurred in 1984 and early 1985. Strikes in Australia and Peru, the earthquake in Chile, and the shutdown of the Bingham pit in the United States early in the year were also factors in reducing world supply. The deficit was eliminated by the third quarter, however, and LME refined copper stocks rose rapidly in response to reduced demand. Although total refined copper stocks decreased in the United States by about 253,000 tons during 1985, commercial stocks outside of the United States increased during the year by about 78,000 tons, according to the World Bureau of Metal Statistics.[46]

Major copper producers started setting their 1986 cathode premium structures in October. CODELCO-Chile lowered its premium for an average pricing by $3.04 to $4.56 per ton and reduced its premium for unknown pricing by $4.56 to $24.30 per ton. All sales in Europe and Japan were to be based on the LME higher grade settlement price through June 30, 1986, and on the new Grade-A contract that was to start July 1, 1986. The Metal Marketing Corp. of Zambia Ltd. (Memaco) announced that its premiums were to be unchanged from the 1985 contract—specifically, a $38-per-ton premium for fixed known prices, and a $30.40-per-ton premium for unknown prices. In addition, Zambia's customers were to be offered less tonnage in 1986 than they contracted for in 1985 since Memaco overcommitted itself for 1985 contracts.[47]

The LME Committee approved four brands of copper wirebar as deliverable against the new Grade-A copper contract approved in late 1985: Chile's CCC/MR, Poland's HMG Zaire's UMK, and Zambia's REC refined copper wirebar brands. Twelve wirebar brands were initially considered.[48]

Exports of copper concentrates increased from Australia, Chile (increased by 100,000 tons), Peru, the United States, and Zaire. Exports of refined copper decreased significantly from Zambia from 530,100 tons in 1984 to 474,500 tons in 1985. Decreased exports of concentrates and refined copper were also reported by Canada. Imports of concentrates by Finland, the Federal Republic of Germany, Japan, and the Republic of Korea were up marginally. Only Belgium, China, India, Italy, the Republic of Korea, and the United Kingdom indicated increased imports of refined copper.[49]

Smelting and refining charges for concentrates that had dropped on international markets from about 8 cents refining charge (R/C), $60 per ton of concentrate treatment charge (T/C) to about 4 cents per pound R/C and under $20 per dry ton T/C in mid-1984, stabilized at yearend 1984, and ranged from 6 to 7 cents R/C and $40 to $50 per ton T/C during 1985. The drop in custom concentrate supplies, owing to mine closures in Canada and the Philippines, was balanced by smelter cutbacks in Japan and smelter closures in the United States.

The Governments of Chile and China agreed in principle that China would buy Chilean copper concentrates and sell Chile petroleum in exchange. The accord was announced near the end of 1985 at the closing of the eighth Sino-Chilean Trade and Commerce Conference. The copper-petroleum agreement was being organized by CODELCO-Chile and the China International Trust Investment Corp. China hoped to become less dependent upon copper imports during the 5-year plan that begins in 1986, according to the China National Nonferrous Metals Import-Export Corp. (CNNMIEC). Cuts in imports would be made possible by increasing domestic output. Imports of copper into China in 1985 were 356,000 tons[50] compared with 254,045 tons in 1984 and 485,863 tons in 1983.

The 12 European Economic Community (EEC) nations will be authorized to export about 30,200 tons of copper scrap and 25,000 tons of copper ash in 1986, according to export quota restrictions set by the EEC. In addition, 10 of the EEC nations will be allowed to export 14,000 tons of copper scrap and 5,000 tons of copper ash to Spain. The levels set were roughly similar to those fixed for 1985 and were presumed necessary to prevent supply shortfalls on European copper scrap markets.[51]

The copper price rise of the late 1970's prompted plans and discussions for new capacity. Many of these had since been placed on hold, but with changing exchange rates, lowered labor rates, and technological and economical innovations, some of these projects were being reactivated or reconsidered in 1985 with lower production costs quoted. Although the yen and other industrialized countries' currencies strengthened vis-a-vis the dollar near yearend, the copper-producing countries' currencies continued to weaken during the year, thereby effectively lowering production costs. The currencies of Australia, Brazil, Canada, Chile, Mexico, Peru, the Philippines, Zaire, and Zambia all weakened significantly against the U.S. dollar during 1985. Projects reactivated in Canada included the Brenda Mine, which had previous production costs quoted at 80 cents per pound. Projects being reconsidered in Chile included Cerro Colorado, previously requiring prices of about $1.10 per pound. In Mexico, a copper price of $1.00 to $1.10 was to have been required to expand the Cananea open pit. In Peru, the Cobriza project had a break-even point of $1.30 per pound, with cash costs in 1984 of about 84 cents per pound for the expanded production. Cerro Verde II sulfide ore would have required 90 cents per pound to break even. Revised plans for a smaller operation indicated a break-even level at only 56 cents per pound. Development plans also were announced during the year at both the Ok Tedi deposit in Papua New Guinea and at the Roxby Downs deposit in South Australia.

**Australia.**—In 1985, average copper prices in Australia were $2,066 per ton, 30% higher than in 1984 mainly because of the relative weakness of the Australian dollar. Australian copper prices began 1985 at $1,600 per ton, the year's minimum, and increased steadily to reach the high for the year of $2,440 per ton on April 29. Prices closed the year at $2,100 per ton.

Western Mining Corp. Holdings Ltd. (WMCH) and British Petroleum Ltd.'s (BP) BP Australia Ltd. announced that the Olympic Dam Project at Roxby Downs would proceed with construction beginning in early 1986. The project was to cost between $550 and $600 million and produce 55,000 tons of copper, 2,000 tons of uranium oxide, and up to 90,000 ounces of gold per year. The initial gold production was to start in 1987 with copper and uranium production to begin in 1988. Copper production was scheduled to begin in 1988 at the rate of 30,000 tons per year, rising to 55,000 tons per year in the second phase. Ore reserve base estimates[52] were given as 2 billion tons of 1.6% copper demonstrated, or about 32 million tons of contained copper. The two firms outlined at the end of 1983 a major high-grade ore body within the main ore body containing probable ore reserves of 450 million tons at 2.5% copper, 0.8 kilogram of uranium oxide per ton, 0.6 gram of gold per ton, and 6 grams of silver per ton. WMCH's subsidiary, Roxby Mining Corp., will be a 51% owner of the project, and BP Australia will hold a 49% interest.

At CRA Ltd.'s mine in Cobar, western New South Wales, the installation of new underground ore handling facilities was completed as part of an expansion project involving development of the lower levels of the mine to raise capacity to about 850,000 tons of ore per year. CRA and the New South Wales government reached an agreement in May that helped to keep the Cobar copper mine open. The government gave undisclosed concessions in return for the company's pledge to spend $4.8 million in development on the deeper ore bodies. The arrangement followed an earlier agreement with unions at the mine that led to major changes in work practices. With these changes, output from the mine was expected to rise from 600,000 tons of ore per year to 850,000 tons per year.

**Belgium-Luxembourg.**—Major projects for the financial year at Métallurgie Hoboken-Overpelt SA's Hoboken facilities included the continued construction of two electric furnaces as part of the smelter modernization program that was started in June 1984. One furnace started up in September 1985; the other was to start up in 1986. In addition, a modernization of the blast furnaces at Hoboken was in process, including an increase in the capacity of one of the furnaces. At Olen, a plant was under construction for the continuous melting and refining of copper in a vertical furnace. Both the feed charging and anode removal operations were to be highly mechanized and operational by mid-1986.[53] Copper smelter capacity at Belgium's two smelters, Beerse and Hoboken, was estimated to be 172,000 tons of blister copper per year. The 100,000-ton-per-year Beerse smelter was owned by La Metallo Chimique SA. Refining capacity in 1985 was estimated to be 480,000 tons of copper per year at Beerse, Hoboken, and Olen.

**Brazil.**—In January, Caraíba Metais S.A. brought on-line its underground mine at Jaguarari, Bahia State. The company was already operating an open pit at the site, producing about 32,000 tons of copper in concentrates in 1985. Output from the new underground mine was expected to reach 15,000 tons per year when at full capacity in 3 years. Production from the Pedra Verde Mine, operated by Guanordeste Mineração e Comércio Ltda. started in 1984 at a rate of 80 tons per month of contained copper. Brazil's state-owned Cia. Vale do Rio Doce was to start up a $6 million pilot plant at the Salobo Mine in Carajás in March 1986. The plant was part of a $600 million development scheduled to come on-stream in 1988. The deposit was estimated to contain 1.2 billion tons of ore with an average grade of 0.85% copper. Cathode production at Brazil's Caraíba Metais refinery was 93,880 tons in 1985, 62,100 tons in 1984, 55,074 tons in 1983, and 2,901 tons in 1982. The smelter has a blister capacity of 150,000 tons per year.

**Burma.**—Mitsui Mining Co. of Japan negotiated a contract during 1985 with Burma's No. 1 Mining Corp. for 15,000 tons of concentrates from the Monywa Mine. Ore reserves at the mine were given as 117 million tons with a grade of 0.734% copper at yearend 1984. Projected life of the mine was estimated at 48 years at current production rates.

**Canada.**—Despite the fall of nickel and zinc prices at the end of 1985, which had a negative impact on Canadian copper production, mine production of copper increased compared with that of 1984 and was well above 1981 and 1982 levels. There was no Canadian producer mining only copper during the year. The largest copper producer was the nickel company Inco, followed by Kidd Creek Mines.

BP Canada Inc. was planning a $125 million project to bring a new zinc-copper-silver ore body into production at Les Mines Selbaie, northwest Quebec, by late 1986. The move follows BP Canada's acquisition of Hudbay (Quebec) Ltd., formerly owned 87.5% by Dome Petroleum Ltd., giving the company two-thirds ownership in the Selbaie Mine. A production of 27,400 tons per year of copper was expected from the open pit mine by November 1987. The Quebec government was to provide 20% of capital costs via a grant of up to $18 million. In December, Esso Minerals Canada Ltd. agreed to purchase a 35% interest in BP Canada's Selbaie operations.

Gibraltar Mines Ltd. was to build a leach facility for leaching waste and low-grade dumps at its copper-molybdenum mine near McCleese Lake, British Columbia. The $12.3 million unit will include an SX-EW plant with 5,000-ton-per-year copper capacity. The mine had been operating at a loss since 1981, producing about 150,000 tons per year of 26.6% copper concentrates with byproduct molybdenum in 1985. Plant construction was to be completed in October 1986.

Less than a month after Noranda put its Rudolf Wolff Group up for sale, the company restructured its operations, splitting Noranda Minerals into three operating groups, Noranda Copper, Noranda Mining, and Noranda Zinc. Noranda Copper included, in increasing order of processing, the Horne smelter, Canadian Copper Refineries (CCR); the Gaspe Div.; Chadborne; Bell Copper; Remnor; and Micrometallic, a computer scrap business in the United States. Noranda Mining will consist of Geco Div. (copper, silver, zinc); Mattabi Mines (copper, silver, zinc); Lynn Lake Div. (copper, lead, silver, zinc); Golden Giant (gold); Central Canada Potash; Brenda Mines (copper, molybdenum); Pamour (gold); and Mining Corp., a mine development contracting concern. A combination of British Columbian government assistance, labor cooperation, and lower electric and tax rates allowed Noranda to reopen its Bell and Brenda copper mines in British Columbia early in September.[84] The British Columbia Legislature recommended in June 1985 that both the Bell and Brenda Mines should be given some Provincial assistance to reopen. Labor contracts were extended without salary increases to June 30, 1987, with the addition of a profit-sharing plan. The company expected to produce 21,300 tons per year of copper in concentrate at the Bell Mine, which had been closed since 1982, as well as 25,000 ounces of gold and 125,000 ounces of silver. Bell had reserves of 42.7 million tons of ore grading 5.1% copper. The Noranda Brenda copper-molybdenum mine only produced for 7 months in 1984, closing on December 14, 1984. Brenda had a capacity of 14,000 tons per year of copper and 6 million pounds per year of molybdenum. Both mines were expected to cease operations by yearend 1988 after exhaustion of economic reserves.

Sherritt Gordon Mines Ltd. took a $23.2 million charge against its 1985 earnings as a provision for write-down of its lower grade ore reserves at its Ruttan Mine in Manitoba. Nonetheless, production was scheduled to increase at Ruttan, with operating plans calling for about 31,300 tons of copper in concentrate plus zinc for 1986 compared with a production of 20,400 tons of copper and 15,900 tons of zinc in 1985. Sheritt's copper and zinc concentrates were sold to the Flin Flon smelter of Hudson Bay Mining and Smelting Co. Ltd.

Lornex Mining Corp. Ltd. and Cominco Ltd. planned to combine their assets in Highland Valley, British Columbia, to form one of the largest copper mines in North America. Annual concentrate output from the combined Highland operations will contain in excess of 180,000 tons per year of copper and significant quantities of gold and silver. Cominco's higher grade Valley Mine had ore reserves of 800 million tons of 0.48% copper plus gold and silver values. The Lornex Mine had ore reserves of 385 million tons of 0.38% copper and 0.03% molybdenum. Cominco and Lornex were to share control and management of the venture, and expansion work was to start in May 1986.

Teck Corp. held 22% of Lornex Mining, which was a member of the Rio Tinto Zinc Group and 68.1% owned by Rio Algom Ltd. Teck also held a 73% interest in the Afton copper-gold mine with Metallgesellschaft Canada Ltd. Afton, which is east of Kamloops, British Columbia, returned to profit during the year, producing 22,400 tons of copper and 48,559 ounces of gold. Rio Algom's East Kemptville tin mine started trial production. About 1,500 tons of byproduct copper in concentrates per year was expected to be produced at full capacity.

Falconbridge Ltd. agreed to acquire Kidd Creek Mines for $446 million from Canada Development Corp. (CDC), an 11% Provincial government-owned firm with investment in chemicals, energy, and mining. Not included was the company's interest in the Allen potash mine and lead-zinc mine on Baffin Island. CDC will receive a 20% stake in Falconbridge as part of the agreement that is to be completed in 1986. Earlier in the year, Dome Mines and its affiliate McIntyre Mines Ltd. had taken a 30% share of Falconbridge, which gained Kidd Creek's newly modernized Timmins metallurgical complex that included a zinc smelter and a copper smelter and refinery. Kidd Creek Mines had invested about $300 million to modernize the Timmins copper refining and smelting plants, which were raised from 59,000 tons of copper per year to a capacity of 90,000 tons per year. Kidd Creek's Timmins smelter, which used the Mitsubishi smelting process, was shut beginning in April for 51 days for major modifications to the smelter acid plant and related equipment as part of the expansion program. The casting line at the copper smelter-refinery also was closed for nearly a month because of an anode furnace spill.

The Quebec government announced regulations in February to control the emission of sulfur dioxide. Noranda's Gaspe and Horne smelters will be required by the end of 1990 to contain 65% and 50%, respectively, of the sulfur entering the plants. The Horne smelter will be also required to contain 35% of the sulfur entering the plant by the end of 1989. Noranda's Gaspe smelter operated through the year with imported concentrates from South America and those produced at the Needle Mountain Mine; the Copper Mountain open pit remained closed.

The Canadian Government was to provide up to $107 million in financial assistance to the smelting industry to cut sulfur dioxide emissions in half over the next 10 years as part of a long-range acid rain cleanup program. The Ministry of the Environment set a target date of 1994 for smelters to reduce emissions by 50% throughout the country. Estimates of the total cost of improving the five largest sulfur dioxide emitters range from $504 million to $720 million.[55]

**Chile.**—Copper production in Chile in 1985 amounted to 1.36 million tons, up about 5% over that of 1984. CODELCO-Chile accounted for 1.08 million tons of the total. The Chuquicamata Div. produced 51% of CODELCO-Chile's mine output, followed by the El Teniente Div., 30%; the Andina Div., 10%; and the El Salvador Div., 9%. CODELCO-Chile reported pretax profits of $437.6 million on revenues of $1.6 million in 1985, compared with $332.6 million on gross revenues of $1.5 million in 1984. Over $411 million was transferred to the Chilean Government during 1985, or about $100 million less than in 1984.[56] Chile received $850.1 million from the IMF for a 3-year funding program. Under the terms of the program, Chile would have immediate access to $60 million in IMF credit and an additional $73.1 million in compensatory financing to make up for loss of export income amounting to $244.5 million during the 12 months ending in March 1985. Most of the shortfall, about $161.6 million, was attributable to a drop in the export volume and unit value of copper. Chile's economic program for the next 2 years, which the loan was aimed at supporting, required an expansion of exports. To stimulate foreign investment, Chile approved changes in the foreign investment code including the extension from 10 to 20 years of the guarantees of a fixed 49.5% tax rate and other tax benefits. Chile was attempting to establish better conditions for financing several copper projects under study, including the Cerro Colorado copper mine and the La Escondida copper mine.[57]

Chile's small- and medium-sized mines obtained a $100 million loan from the World Bank. One-half of the money was to be used by ENAMI to improve the efficiency of its Ventanas refinery, two smelters, and several concentrators, and the rest for mine development and other investments at small- and medium-sized mines. In 1985, La Sociedad Nacional de Minería (SONAMI) members produced 263,900 tons of copper, up from 257,000 tons in 1984.

CODELCO-Chile expected to invest $310 million in its four operating divisions in 1985, and another $300 million during 1986 to maintain existing production levels. Of the planned investments, $97 million was to go toward pollution control. CODELCO-Chile noted that about $250 million already had been invested in environmental protection equipment at Chuquicamata Div. Planned investments at Chuquicamata included $17.7 million for a refinery program, $22 million for a flash smelter and related equipment, $13.6 million for a sulfuric acid plant for the flash smelter, and $81 million for power improvements. At El Salvador Div., $6 million was allotted for mine development, and at Andina Div., $5.4 million for tailings disposal. At El Teniente Div., mine infrastructure was to receive $39.2 million; transport and storage of tailings, $20.1 million; and expansion of the Colon concentrator, $14.1 million. CODELCO-Chile planned to invest $1,200 million at its Chuquicamata Div. over the next 5 years.

CODELCO-Chile was to begin development of two new mines, Chuquicamata Norte and Elabra. Copper production capacity was to be raised at Chuquicamata from the current rate of 550,000 tons of copper per year to about 850,000 tons per year upon completion of the investment. The concentrator was to be expanded to 153,000 tons of ore per day by 1987. A new 30,000-ton-per-day in-pit ore crusher recently was installed. About 100,000 tons of ore per day was processed with an average grade of 1.6% copper, yielding about 4,000 tons of concentrates per day from the Chuquicamata pit, which was about 2 kilometers wide, 3.8 kilometers long, and 478 meters deep. Reserves were estimated at 1.7 billion tons of copper ore containing an average of 1.04% copper.

A $90 million, 4-year investment program at the Andina Div. of CODELCO-Chile was completed on March 31, boosting annual copper production capacity to 118,000 tons of contained copper per year. Andina's open pit Sur Sur Mine was used to supplement the block-caving operation in the Cerro Blanco ore body. CODELCO-Chile planned to increase production from the current 20,000 tons of ore per day to 26,000 tons per day by 1987 to compensate for an expected drop in average ore grade.

In March, El Teniente suffered earthquake damage to its tailings flume, concentrator, and Caletones smelter. The ports of San Antonio and Valparaíso and several roads and rails were also damaged, delaying copper deliveries.

The underground mine at El Teniente was CODELCO-Chile's second largest producer, with reserves estimated at 47.6 million tons and an average ore grade of about 1.2% copper. The mill-head grade of 1.4% copper was expected to fall to 1.2% copper by 1989 and to 1.0% copper by the end of the century. Ore treatment capacity was expanded during 1985 to 80,000 tons of ore per day.

El Salvador Div. was an underground block-caving operation and associated concentrator, Potrerillos smelter, and refinery. Situated in the Atacama Desert, the mine had a capacity of about 34,500 tons of ore per day, producing 710 tons of 38% copper concentrate per day and 6.5 tons of 56% molybdenum concentrate per day. El Salvador had 20 to 30 years of ore reserves with an average grade of about 1% copper and 0.023% molybdenum.

Antofagasta Holdings of the United Kingdom acquired the Los Pelamberes copper-molybdenum deposit for $6.4 million in northern Chile from Anaconda Minerals near yearend. Anaconda Minerals had postponed the project after it was unable to find partners to provide part of the $1 billion to $2 billion needed to develop the ore, which had about 400 million tons of ore grading 0.9% copper and 0.015% molybdenum.

Texaco Oil Co. sold its 50% share in the $1.3 billion Escondida project to a consortium comprised of The Broken Hill Pty. Co. Ltd. of Australia (BHP) (10%), Rio Tinto Zinc Corp. Ltd. (30%), and Mitsubishi Corp. (10%). The purchase price was less than $100 million, and brought BHP's stake to 60%, which it held through its subsidiary, Utah International. The consortium was starting a yearlong feasibility study and was arranging financing and sales contracts. Mine production was planned for 1990 and called for an open pit, a 160-kilometer slurry pipe, and port facilities. Projected annual production was 300,000 tons of copper in concentrate per year. Escondida is one of the richest undeveloped copper deposits in the world with proven reserves of 545 million tons of ore grading 2.16% copper and 0.01% molybdenum. Most of the concentrate was planned for shipment to Japan for smelting.

Cía. Minera San José Ltda., a subsidiary of St. Joe Minerals Corp., operated two open pits at the El Indio Mine, 420 kilometers north of Santiago. El Indio had reserves of 4.6 million tons of 5% copper as well as 9.6 grams of gold per ton and 122 grams of silver per ton.

Cía. Minera Disputada de las Condes S.A., an Exxon Minerals Chile Inc. subsidiary, approved a 2-year, $73 million expansion project at the company's El Soldado Mine and El Cobre treatment plant. The decision was made despite Disputada's continuing losses, which were about $41.5 million in 1984. Since taking it over from ENAMI in 1978, El Soldado had never been profitable.[58] Disputada produced about 77,000 tons of copper concentrate in 1985 compared with 61,575 tons in 1984. The increase was from higher production at El Soldado, where a concentrator expansion completed in September 1984 boosted capacity to 5,500 tons of concentrates per day from 3,700 tons per day. Exxon Minerals was studying a $70 million to $80 million expansion that would increase the rate at El Soldado to 11,500 tons per day. Startup of the operations was scheduled for the second half of 1987. Of a total $71 million to be invested in the expansion project, $23.6 million will be spent on the El Cobre plant. Current reserves at El Soldado were estimated at 48 million tons of 1.7% copper. The company was also looking at a $350 million to $400 million expansion at Los Bronces.

Development of the Cerro Colorado copper deposit in Chile was delayed indefinitely after Finland withdrew its planned support. The project was to cost $240 million with contributions coming from Canada's Rio Algom ($60 million), the West German Government ($80 million), the Finnish Government ($35 million), and the Chilean State Economic Corp. ($30 million). In addition, the United Kingdom's export credit guarantee department agreed in principle to secure bank loans amounting to $35 million for purchase of domestic equipment and engineering services. Chile's industrial development corporation, Corporación de Fomento de la Producción, was also to loan

$30 million. Production of 60,000 tons of copper per year was planned for about 1988. Nippon Mining Co. Ltd., Tokyo, Japan, previously had abandoned the project in 1980 because of uninspiring cost-benefit prospects. Cerro Colorado's resources are estimated at 70 million tons of about 1.3% copper.

Chuquicamata Div.'s smelter consisted of four reverberatory furnaces, seven Peirce-Smith converters, and one modified Teniente converter and had a capacity of 1,500 tons of cast anodes per day. Sulfuric acid production at the smelter was to be increased from 500 to 3,000 tons per day by 1989, and a new 200,000-ton-per-year flash smelter was to be added by 1990. Anode casting capacity was to be increased to 1,800 tons per day. Mitsubishi of Japan signed a $78 million contract to build the new acid plant, providing 100% of the project's financing.

CODELCO-Chile's El Teniente Div.'s smelter at Caletones had an annual capacity of about 340,000 tons of blister copper from two reverberatory furnaces and two Teniente converters. The only modernization projects at the Caletones smelter were the addition of converter hoods and improvement of casting facilities. The new fire-refining furnace at the Caletones smelter had production problems upon startup in February. The company's Potrerillos smelter was about 50 kilometers from the El Salvador Mine and was equipped with one reverberatory furnace, four Peirce-Smith converters, two cylindrical refining furnaces, and one anode casting wheel. The plant's capacity was estimated to be about 100,000 tons of blister per year.

ENAMI's Ventanas smelter, which had an annual blister capacity of about 110,000 tons per year, was damaged in the March earthquake, but was functioning again within 30 days. ENAMI buys raw materials for the Ventanas smelter from the small-mine sector as well as from CODELCO-Chile. ENAMI was spending $4.5 million on the Ventanas complex to increase its refining capacity to 195,000 tons per year, which would be realized by January 1986. An investment of $30 million was planned to build a sulfuric acid plant that would produce 525 tons of sulfuric acid per day.

Considerable expansion of the Chuquicamata refinery was under way, and production was expected to reach 475,000 tons per year by yearend 1986. In 1985, electrorefining capacity in two existing tankhouses was about 400,000 tons per year. Refinery No. 1 was designed for electrowinning copper from leach solutions and would be completely replaced by the $70 million expansion. In 1985, CODELCO-Chile's only oxide treatment was done at Chuquicamata in the electrowinning facilities of refinery No. 1. About 40,000 tons of electrowon cathode per year was being produced through this method, but was expected to be doubled over the next 4 years using oxide ores at Mina Sur, low-grade ore dumps from the Chuquicamata Mine, and waste dumps at both Mina Sur and Chuquicamata. This expanded leaching was expected to be in operation by 1988, followed by cessation of vat leaching. The Potrerillos refinery at El Salvador also was originally designed for electrowinning and later converted to electrorefining. Expansion to 96,500 tons of copper cathode per year was completed in 1984, raising the capacity to equal the smelter. CODELCO-Chile postponed indefinitely the construction of a new 100,000-ton-per-year copper refinery 50 miles from Santiago, originally planned to treat blister copper from the El Teniente and Andina Mines. The refinery was to come on-stream in 1987. The existing El Teniente refinery had a capacity of about 155,000 tons of copper cathode in 1985.

CODELCO-Chile's Chuquicamata Div. held a near monopoly in Chile as a supplier of wirebar, and domestic fabricators claimed that they paid more for this wirebar than fabricators in other countries, including those in the United States. CODELCO-Chile owned equity in copper fabrication plants in Europe and was considering a joint-venture in China for a wire and cable plant. Prospects for downstream expansion of fabrication plants in Chile were limited because of the country's small domestic market and higher tariffs in export markets on fabricated products compared with tariffs on refined copper. Total output of fabricated copper products in Chile was about 35,000 tons per year, of which about 60% was exported, chiefly to other South American countries.

**China.**—Copper imports totaled 356,000 tons valued at $480 million in 1985, while domestic mine production was only about 185,000 tons. China's trade of all nonferrous metals was to be handled exclusively by the new CNNMIEC, the trading arm of China National Nonferrous Metals Industry Corp. (CNNMIC), beginning in 1986. The responsibility had previously been held by China National Metals & Minerals Import-Export

Corp.

CNNMIC was seeking technology and investments from foreign interests for 18 nonferrous metals joint venture projects, including a 5,000-ton-per-year copper tubing and a 1,000-ton-per-year copper sheet and strip plant in Beijing; a high-accuracy copper alloy strip processing line, with a capacity of 4,000 tons of brass strip per year and 3,000 tons of radiator and cable strip per year; and a copper foil plant, with a capacity of 1,000 tons per year at the Shanghai copper smelter complex; a beryllium bronze processing line with annual capacity of 2,000 metric tons at the Northwest copper fabricating plant; a mill to treat 1.5 million of ore per year at Huili Lala copper mine, Sichuan Province; and construction of a mine and a concentrator in the Jiangxi copper complex at the Chengmenshan copper mine.

Continuus-Properzi Corp. signed a sales contract with Wuhu Smelter, a copper refining and fabricating company of Wuhu City, Anhui Province, for the supply of a Properzi continuous cast copper rod line to be operating by the end of 1986. This was the third Properzi copper rod line recently sold to China. China planned to have at least 12 continuous cast copper rod mills in operation by 1987. Total capacity of the mills was estimated at about 390,000 tons of rod per year, with much of the output destined for use in telecommunications and magnet wire applications. CODELCO-Chile held discussions with representatives of CNNMIC for a possible joint venture to build an $8 million copper cable and wire plant near Beijing.

China's 5-year plan projected copper production at 150,000 tons per year in Jiangxi Province by 1990 and 200,000 tons per year by 1995. Production at Jiangxi's copper mines was 70,000 tons in 1985. The producing mines were in the northeast region of Jiangxi Province and included the Chengmenshan, Dexing, Dongfang, Wushan, Yinshan, and Yongping copper mines near Poyang Hu. This area accounted for nearly one-third of the national production. The Yongping open pit, which started in 1984, was producing 500 tons of concentrates per day. Reserves were estimated to be more than 74 million tons.

A joint Yugoslav-Chinese agreement for exploitation of a copper mine in the Province of Sichuan was reactived. The Yugoslav company, Bor Mining and Metallurgical Works Co., was to construct an open pit mine with a capacity of about 2.5 million tons of ore per year.

China has copper resources at more than 800 sites, including nearly 30 large copper deposits. The ores are mostly low-grade with an average copper content of 0.6% to 1.0% and many with less than 0.5%. There were no extremely large deposits; most have resources of less than 5 million tons and many lie at such depths and in such remote places as to be impractical to develop at present. Skarn copper deposits were China's main potentially commercial copper ores and occur in the middle and lower Changjiang Basin, the eastern section of northeast China, the Yanshan and Nanling mountain areas, and the southwest. Porphyry copper ore types made up about 45% of available resources and associated skarn deposits about 28%.[59]

New refining equipment was installed at the No. 2 refinery of the Tongling Nonferrous Metal Co. The annual capacity at the refinery was to be increased from 30,000 tons to 45,000 tons of copper cathode through the new addition.

China's Tianjin Nonferrous Metals Co. and Noranda were to undertake a feasibility study that could lead to the construction of a 100,000-ton-per-year copper complex at Tianjin in northeastern China by the early 1990's. Noranda would provide technology for a smelter, refinery, acid plant, and oxygen plant. The complex was estimated to cost about $200 million and would process foreign copper concentrates. The study would be funded largely by the Canadian International Development Agency's Industrial Development Div. and would be completed by 1987. Noranda would hold a minority share in the project.

Jiangxi Copper Corp.'s Guixi smelter was completed in December after more than 5 years of construction. The initial production was to be at a rate of about 90,000 tons of copper blister per year and about 340,000 to 360,000 tons of sulfuric acid per year. When fully complete, the smelter's annual capacity was planned for 200,000 tons of copper and 860,000 tons of sulfuric acid per year. Most of the equipment and technology used for the smelter was purchased from Sumitomo of Japan and Outokumpu Oy of Finland.

**Colombia.**—Nittetsu Mining Co. Ltd. of Japan formed a joint venture with Minas del Cobre Ltda. to develop the El Cobre copper mine in Colombia. Starting in 1986, the mine and infrastructure development would start production for 2 years at a rate of 4,000 tons of copper in concentrate per year. The mine, 80 kilometers southwest of Medellin, had reserves of 1 million tons with an average grade of 4% copper and 3 grams of gold per ton.

**Indonesia.**—Freeport Indonesia Inc., an 81% owned subsidiary of Freeport-McMoRan Inc., produced copper concentrates from two mines in Irian Jaya. Copper production set a new record high in 1985 at 88,700 tons of copper in concentrates produced. The Ertsberg East Mine accounted for most of it. Copper reserves at yearend 1985 were 846,000 tons in ore, according to the company's annual report, compared with 993,500 tons at the end of 1984. Work continued on evaluation of deep reserves at Ertsberg East.

**Japan.**—Electrolytic copper production was almost the same as in 1984 while consumption of refined copper was down to about 1.2 million tons during 1985 from the 1984 record high of 1.37 million tons. Communication cable shipments in Japan were 21% below 1984 levels and exports were halved. Electrical power cable shipments increased and were 14% above 1984 levels as a result of increased public housing and power generation investments. Production of copper pipe and tubing was down by about 4.6% in the second half of 1985, compared with the first half, as a result of a drop in exports and a sharp production fall of air conditioners; both were presumed to be the result of the increasing value of the yen. Imports of refined copper cathode were 351,000 tons in 1985, down sharply from 463,000 tons in 1984. The decline was explained in terms of reduced economic expansion and an accompanying fall in demand for finished products.[60] Exports of 51,000 tons of refined copper in 1985, on the other hand, were higher than the rather low figure of 18,400 tons reported for 1984. Alloy ingots and scrap exports were also much higher than in 1984. Although wire rod exports to China were down, exports of cathodes to China in 1985 jumped to 39,102 tons and accounted for 77% of Japan's total cathode exports, compared with only 378 tons in 1984. Imports of concentrates were at an increased level of 812,600 tons contained copper in 1985, compared with 785,000 tons in 1984 when concentrate market tightness forced a cutback on imports.

Nineteen Japanese zinc and copper producers made applications for assistance from the Ministry for International Trade and Industry's (MITI) emergency loan fund in 1985. MITI announced it would lend $12.5 million at an interest rate of 3% to 16 domestic copper and zinc mines in fiscal year 1986-87. The loan arrangement was set up in 1978 to help the mines maintain production while nonferrous metal prices remained low. The changing picture in 1985 was blamed on the strengthening yen against the dollar.

Japanese smelters continued to operate at a reduced output in 1985. Japanese smelters had begun to reduce operating capacity to about 1,348,000 tons of metal per year 2 years ago with the closure of the Hitachi, Ibargi (84,000 tons), and Okayama (7,200 tons), smelters. Mitsui Mining & Smelting Co. Ltd. was to stop smelting at its Hibi, Okayama, smelter (39,600 tons) in 1986 and planned to toll process at the larger Tamano, Okayama, smelter (164,000 tons), which was a joint venture with Mitsui (25%), Nittetsu Mining (20%), and Furukawa Mining Co. Ltd. Godo Shigen Sangyo Co. intended to stop blister copper production at its Miyako, Iwate, smelter at the end of May 1986. Although the smelter had two furnaces with a combined blister capacity of 36,000 tons per year, only one furnace was utilized, producing about 2,000 tons of blister per month for export only. Dowa Mining Co. Ltd. completed the installation of new oxygen blowing facilities at its Kosaka smelter. This will increase capacity to 66,000 tons of blister per year. Nippon Mining decided to shut down the Sagnoseki flash furnace for 6 months. Nippon said that this did not affect electrolytic output during the year because the company was able to process from blister copper stocks. The Saganoseki flash furnace was producing about 19,100 tons of cathode copper per year, about 15% below previous levels.

Furutobe Mining Co. Ltd. expected to close its copper-lead-zinc mine in the Akita Prefecture by the end of January 1986 because of ore reserve exhaustion. In 1985, Furutobe produced 10,000 tons of copper concentrates.

**Mexico.**—Domestic demand for refined copper was about 118,000 tons in 1985, nearly double that of 1984. Smelter expansions were well under way at Mexicana de Cobre S.A. (44% state-owned) and Cía. Minera de Cananea S.A. (92% state-owned). When completed, the two smelters would raise Mexico's total smelter capacity to about 362,000 tons of blister per year, reducing Mexico's role as a major exporter of concentrates. Mexicana de Cobre was completing a $400 million smelter that would have an annual capacity of about 180,000 tons of blister per year. The company also planned to complete a $250 million concentrator expansion at La Caridad to 150,000 tons per year by early 1986. Cananea, Mexico's leading blister producer, completed its $250 million expansion program to raise concentrate capacity from 40,000 to 150,000 tons of 26% concentrate per year. Cananea's blister capacity was to be increased to 125,000 tons per year by 1986. The company expected to export about 95,000 tons of the added concentrate production per year. About 40% of the concentrates were to be sold to Japan on a long-term basis, with the rest going to the Republic of Korea, Taiwan, China, and Europe, in order of volume. Cananea was also to install a 22,000-ton-per-year SX-EW plant at its mine in 1986, using refining technology from M.I.M. Holdings Ltd. of Australia.

The United States and Mexico negotiated a three-part environmental agreement that included a commitment by both countries to control sulfur emissions from the two Mexican smelters and the Phelps Dodge Douglas smelter in Arizona by January 2, 1988. The Mexican Government pledged to stop uncontrolled emissions from the Cananea and Nacozari smelters. Both smelters were expected to be operational by 1986. Nacozari, alone, was expected to emit about 400,000 tons of sulfur per year. Since the plant is only 55 miles south of the Arizona border, U.S. officials were concerned about the risk of acid rain damage. Plans to bring the two Mexican smelters into environmental compliance by 1988 may be delayed because of repair costs from the destruction from the September earthquakes.

**Papua New Guinea.**—Bougainville Copper Ltd. plans to alter its copper concentrate marketing plan when sale contracts expire in 1987. Contracts with the Federal Republic of Germany, Japan, and Spain accounted for most of the shipments under contracts initiated in 1972. However, since the mine opened, the company expanded sales to China and the Republic of Korea and was beginning to view the Asia-Pacific region as its prime market. Bougainville Copper produced 175,000 tons of copper in concentrates during 1985, up from 164,500 tons in 1984, according to the company's annual report. The increase was due to an increase in ore milled to 50 million tons from 47 million tons, while the grade remained unchanged at 0.42% copper. A new ball mill came on-stream in late 1985.

In early 1985, the $1,400 million Ok Tedi gold-copper project was the subject of a major dispute between the Government and its foreign partners. The Government was concerned that its partners might abandon the project once the gold-rich cap had been mined, while the partners were not prepared to commit themselves to a firm timetable for developing the copper deposit in view of the depressed market. The Government gave the operating company, Ok Tedi, a formal notice to close down the mine, but after lengthy negotiations, the Government endorsed a revised agreement allowing for variations in the mining plan and transfer of some of the debt from the operating company to the shareholders. Construction of a permanent tailings dam was to be deferred by 4 years, but copper mining was to start 2 years earlier than the initial date. The Government was to restore its stake in Ok Tedi to 20%. Shareholders in Ok Tedi were BHP with 30%; Standard Oil of Indiana (Amoco Minerals), 30%; Metallgesellschaft AG and Degussa AG, each with 7.5%; and the state-owned West German development company, Deutsche Gesellschaft Fuer Wirtschaftliche Zusammenarbeir (Entwicklungsgesellschaft) mbH, 5%. Copper production was scheduled to begin by yearend 1986 at about 30,000 tons of copper in concentrate per year, rising to 60,000 tons per year by mid-1988. A feasibility study completed in 1979 revealed minable ore reserves of 410 million tons, comprised of 351 million tons of porphyry copper ore that averaged 0.7% copper and 0.6 gram of gold per ton at a cutoff of 0.4% copper, and 25 million tons of skarn copper ore averaging 1.17% copper and 1.6 grams of gold per ton. Ok Tedi purchased Anaconda Minerals' Carr Fork, UT, concentrator for $7 million and was expected to have it shipped to Papua New Guinea and have it installed by August 1986 as part of its long-term plan to increase production. By buying secondhand equipment, costs of the copper milling expansion project could be contained to about one-half the cost of new equipment. Ok Tedi was projecting a break-even point of 42 cents per pound for the mine at peak copper output.

**Peru.**—The mining sector contributed about 50% to Peru's total export revenue in 1985. Copper exports from Peru increased in 1985 reaching a total of 350,800 tons (copper content of ores, blister, and refined copper) compared with 1984 exports of about 290,500 tons.[61]

Almost all large-scale mining operations in Peru were owned and operated by state-owned Empresa Minera del Perú (Minero Perú), Empresa Minera del Centro del Perú (Centromín Perú), and Empresa Minera del Hierro del Perú. Southern Peru Copper Corp. (SPCC), which operated two open pits, Cuajone and Toquepala, and Cía. Minera Pativilca S.A., which operated the Raul deposit, were Peru's largest private copper producers. When the new Peruvian Government took office on July 28, 1985, one of its priorities included the reorganization of state mining companies on a regional basis. According to the Government's plan, Minero Perú in its present form would disappear. Centromín Perú would remain essentially a central Peruvian company, and new companies would run operations in the south and the north. Several projects were to be given priority, including development of the Antamina copper-zinc project, a milling operation of about 3,000 tons per day using surplus equipment from the Cobriza copper mine. A mixed private and Government company would fund the project. A scaled-down version of the Cerro Verde II project would be financed at $40 million. Foreign investment in the Tintaya copper mine was also to be encouraged. Subsidies and financing would be provided to keep small- and medium-sized mines in operation when necessary.

Peru broke off negotiations with Japan's Marubeni Corp. and Mitsui for the $130 million financing package for the Cerro Verde II copper project near Arequipa. Nevertheless, Minero Perú hoped to keep the Cerro Verde Mine going through two smaller projects after production from the oxide ores ceases in late 1986. One plan involved recovering copper from the oxide ores at the Tintaya Mine, which started production in early 1985. The second plan would process the higher grade sulfide ores at Cerro Verde by construction of a smaller concentrator. The scaled-down production plan would require an investment of about $22 million versus $278 million estimated for the original Verde II plan and would use crushing machinery already at the mine. Cerro Verde I copper oxide reserves were expected to be depleted by October 1986. Production was down to 28,000 tons of electrowon copper cathode per year from 33,000 tons per year because of declining oxide reserves.

Financing for an expansion project at Centromín Perú's Cobriza Mine was supported through loans from the Inter-American Development Bank ($63.4 million), Wells Fargo Bank ($55.1 million), Peruvian Government ($37 million), World Bank ($36.4 million), Corporación Financiera Desarrollo (Cofide) ($33.8 million), Centromín Perú ($29.9 million), U.S. Export-Import Bank ($3.1 million), and the Sweden Export Bank ($2.5 million). In 1985, 528 people were employed at Cobriza, 126 at the concentrator, and 402 at the mine. The underground mine and 2,360-ton-per-day concentrator were 160 kilometers from the smelter at La Oroya.

Cía. Minera Condestable S.A., one of Peru's medium-sized mines, increased capacity from 1,100 tons of ore per day to 1,300 tons per day. Condestable handled about 400,000 tons of ore in 1985, producing 18,000 tons of concentrates containing 26% copper, plus gold and silver. The mine reportedly had a production cost level of about 55 cents per pound. A further expansion to 1,600 tons of ore per day was planned for 1986.

SPCC's Cuajone and Toquepala Mines were Peru's most prolific copper producers, recovering a combined total of 272,000 tons of contained copper in 1985, 3,800 tons of molybdenum in concentrate, and 2.8 million ounces of silver in blister copper.[62] Estimated ore reserves at the Cuajone Mine at yearend were 300 million tons averaging 0.88% copper and an average of 0.02% molybdenite. The grade of ore had fallen from 0.92% in 1980 to about 0.89% in 1985, a trend that was likely to continue. To maintain production levels, SPCC expanded concentrator throughput from 41,000 tons per day to 50,000 tons per day by installation of improved monitoring equipment and other efficiency improvements. SPCC's Toquepala Mine had a capacity to produce about 50,000 tons of ore and 45,000 tons of waste, based on a 6-day workweek. As of January 1986, a total of 109 million tons of sulfide ore grading 0.81% copper and 0.023% molybdenite remained in the pit. About 27 million tons of low-grade sulfides were stockpiled for future heap leaching recovery.

Empresa Minera Especial Tintaya S.A., a state-owned company formed by Minero Perú (45%), Centromín Perú (45%), and Cofide (10%), started shipments of copper concentrates from the Tintaya open pit mine in August. The $326 million Tintaya copper project was expected to reach capacity in 1986 of 170,000 tons of 33% copper concentrates per year containing 4 ounces of silver per ton and 0.14 ounce of gold per ton. Based on proven reserves of 34 million tons of ore grading 2.12%, the life of the mine was estimated at 13 years. There was also 8 million tons of 2.75% copper in oxide ore that was to be stockpiled for future recovery. A Tucson, AZ, company was doing metallurgical studies to determine the best method to recover this copper, including the possibility of making copper sulfate and shipping it to Minero Perú's Cerro Verde Mine for conversion to refined copper in its SX-EW plant. Financing was provided by $100 million from the Canadian Export Development Corp. and $115 million from the Bank of Nova Scotia and the Toronto Dominion Bank.

Centromín Perú's La Oroya reverberatory smelter treated combined copper, lead, and zinc concentrates. About 80% of the feed was from Centromín Perú's operations. The total labor force at La Oroya was 5,500. Two reverberatory furnaces and six converters were used for copper. Blister copper was fire-refined to 98% copper anodes containing some gold, silver, and 0.3% lead, which were sent to Centromín Perú's La Oroya electrolytic refinery at Huaymanta. In 1983, the refinery produced about 47,000 tons of refined copper, of which 24,000 tons was marketed as 250-pound wirebars, 21,000 tons as copper rod, and 2,500 tons as cathodes.

Private investors in Peru, Spain, and Venezuela opened a brass mill in Trujillo, northern Peru. The new 5,000-ton-per-year brass operation was named Peru Venezuela España S.A. (Pvesa) and made its first shipment of free-cutting brass rod and forging brass to the United States in early July. Minpeco USA Inc., a subsidiary of the state-owned marketing company Minero Perú Comercial, was the U.S. marketing agency for the mill. About 25% to 30% of the plant's production was to be consumed by Industrious Reunidas S.A., a Lima-based brass fabricator that owned 80% of the Pvesa stock. The primary product was copper brass bar and alloy 260 strip.

**Philippines.**—The Philippine Government accepted bids for the 100,000-ton-per-year ASEAN Copper Products Inc. copper semifabrication plant in 1985. The project owners, the Association of Southeast Asian Nations (ASEAN), were owned 60% by the Philippine Government and 40% by the Governments of Indonesia, Malaysia, Singapore, and Thailand. The Government also offered the Philippines Associated Smelting and Refining Corp. (PASAR) smelter for privatization during the year. Three Japanese companies already held 30% of the preferred shares. About 44% of its output went to Japan, 19% to Taiwan, and the rest to China, the Republic of Korea, and various traders. Exports of copper concentrates fell from 462,549 tons in 1984 to 376,674 tons in 1985. Copper cathode exports were 136,495 tons in 1985. Mine production fell as a result of the closure of two mines by Atlas Consolidated Mining and Development Corp. However, the Japanese company Marubeni provided $12 million to assist in reopening of the Sipalay Mine in return for 90% of the concentrates. The state-owned Maricalum Mining Corp., which was created out of the bankrupt Marinduque Mining and Industrial Corp. group of companies in July 1985, planned to increase the daily ore milling rate at the Sipalay Mine to 40,000 tons per day by early 1986.

**Poland.**—Refined copper production amounted to an estimated 387,000 tons in 1985, 70% of which was sold as cathode and 30% as semifabricates (rod). About 180,000 tons of unwrought copper was exported. Principal export destinations were the Federal Republic of Germany, Romania, and the United Kingdom. The Polish copper industry was managed by Kombinat Gorniczo-Hutniczy Miedzi and employed about 43,000 workers. There was a labor shortage in 1985, reportedly because of low pay in the copper mines. About 10% to 20% of future copper industry investment budgets were related to environmental costs and called for emphasis on finished products. About 75% of the concentrates mined were treated in shaft furnaces at Legnica and Glogow with the remainder treated by a modified Outokumpu flash smelter at Glogow II.

**Portugal.**—A 49% interest in Sociedade Mineira de Neves-Corvo S.A.R.L. (Somincor) of Portugal, which was previously held by Penarroya S.A. and Compagnie Française des Mines S.A. of France, was sold to Rio Tinto Zinc in mid-1985. The other 51% of Somincor was state-owned. The $200 million Neves-Corvo copper project was expected to produce about 65,000 tons of copper in concentrates by yearend 1988 from a 25-million-ton ore body having an average grade of about 3.2% copper. In addition to the main ore body, there were 40 million tons of copper-lead-silver-zinc reserves. In

November, Quimica de Portugal E.P., a state-owned company, invited tenders for design and construction of a 100,000-ton-per-year smelter, refinery, acid plant, and associated infrastructure estimated to cost $300 million.

**U.S.S.R.**—Based on a detailed study of U.S.S.R. copper mine, smelter, and refinery trends that was completed by the U.S. Bureau of Mines in 1984,[63] capacity and production figures for the Soviet Union were significantly reduced from previous estimates by the Bureau. The growth of the U.S.S.R. copper industry during the past 65 years was analyzed in some detail on a mine-by-mine and plant-by-plant basis and, when compared with the last known published official figures, indicated an overall lower growth in Soviet copper production and capacity than had been previously estimated. The principal geological features of the deposits and an analysis of ore reserves were described by the report as well as historical trends in mining, beneficiation, metallurgy, and supply-demand relationships. Copper production capacity for the U.S.S.R. was estimated to be, in thousand tons of copper content, as follows for 1985: mine, 680; smelter, 980; and refinery, 1,100 tons per year.

**Zaire.**—La Générale des Carrières et des Mines du Zaire (Gécamines) began a 5-year, $750 million investment program to stabilize copper production through the rehabilitation and modernization of the mining, concentrating, smelting, and refining operations. Of the total, $500 million was to be financed through retained earnings with the remainder financed by multilateral development banks with bilateral cofinancing. The goal was to renew aging plants and to increase the in-country value added through additional refining. Almost one-half of Zaire's production was either blister or standard-grade cathode, both of which required further refining in Europe. The plan called for the construction of a 100,000-ton-per-year copper smelter and refinery complex at Luilu in Kolwesi.

In July, the direct marketing control of all copper and cobalt was taken over by Gécamines Commerciale from the Belgian company SGM-Afrimet. This followed a major corporate restructuring last year involving the formation of Gécamines Holdings to oversee the activities of three separate operating subsidiaries responsible for mining, development, and marketing.

Gécamines was under pressure from the Government to use the state-owned railway, Voie Nationale, in a bid to increase revenues for the railway. The railway was to handle 60% of material shipped in 1986 with only 30% to be sent through South African ports. Gécamines was countering transportation problems between Lubumbashi and the Port of Matadi in early 1985 and turned to increasing shipments via the quicker southern route, with about 43% of Gécamines output exported via the Republic of South Africa and Zambia; about 11% was being sent through the Port of Dar es Salaam in Tanzania.

**Zambia.**—For the year to March 31, 1985, Zambia Consolidated Copper Mines Ltd. (ZCCM), which was 60.3% Government-owned, reported a pretax profit of $62 million. This was achieved against a background of rising costs, lower copper prices, and continued deterioration of production owing to poor plant and equipment availability. Following this achievement, however, ZCCM incurred a net loss of $15 million in the 9 months to December 1985. In addition to hard currency shortages, ZCCM was also plagued by railroad shipping problems, although new locomotives had been introduced on the Tanzanian Railway. Shortages of spare parts and diesel fuel, coupled with a strike in June by 8,000 workers, resulted in a drop in annual mine production to about 483,000 tons. Some material was imported during the year from Zaire to be smelted and refined in Zambia. Since 1984, ZCCM had been undertaking an export, rehabilitation, and diversification program where the main objective was to enhance corporate viability by improving productivity and efficiency. It was being funded by the World Bank, the EEC, and the African Development Bank, together with funds from ZCCM's own sources. The European Commission announced approval in October of a $23.2 million loan to Zambia. The Italian Government was also to make a grant to help complete ZCCM's rehabilitation program and cover the purchase of equipment for mining and processing. ZCCM was to embark on a recruitment campaign for qualified and experienced specialists both locally and overseas. As of November, about 1,633 expatriates were employed at the mines, or about 2.7% of the work force.

Zambia, started a major reorganization of its copper industry at yearend 1985, which, while initially trimming about 50,000 tons of annual production, was ultimately designed to restore the health of the industry. The 5-year plan, which was to start in January 1986, called for the closure of the Kansanshi (6,000 tons per year) and Chambishi (26,000 tons per year) Mines and the No. 3 shaft at the Konkola Div. (output 20,000 tons for year ending March 1985). The mines were to close as soon as developed ore reserves were exhausted. The mines have been beset by Zambia's acute economic problems. A severe shortage of trucks reduced Kansanshi Mine's effectiveness. In 1985, about 162,000 tons of ore was brought to the surface, but only 77,000 tons was moved from the minesite. As of March 31, 1985, undeveloped reserves at Kansanshi stood at 3.4 million tons grading 2.75% copper, while those at Chambishi totaled 20.9 million tons grading 2.78% copper, and at Konkola, 45.1 million tons grading 3.84% copper. Also included would be the shutdown of the Chambishi concentrator, Luanshya smelter, Ndola copper refinery, and the Nkana oxide concentrator. About 3,000 workers will lose their jobs. The Konkola Div. and Nchanga Div. would be merged, leaving ZCCM with four mining divisions: Luanshya, Nchanga, Nkana, and Mufulira.

The $250 million Stage II Nchanga tailings leach project started treating tailings in mid-December, and at full capacity, which was to occur in August 1986, was expected to recover about 50,000 tons of lower cost copper per year that will help to offset production loss from planned closures. The Kafironda explosives factory in Zambia, the sole supplier of industrial explosives to ZCCM, was to resume full production in early 1986.

**Zimbabwe.**—The former South African-owned Messina (Transvaal) Development subsidiary, M.T.D. (Mangula) Ltd., which produced about 90% of Zimbabwe's copper, changed its corporate name during the year to Mhangura Copper Mines Ltd. and changed the brand name of its standard copper cathode produced at its refinery to Mhangura from Mangula. This followed the sale of Messina's assets (55% of Mangula and 65% of Lomagundi Smelting and Mining Co.) to the Government-owned Zimbabwe Mining Development Corp. (ZMDC) in September 1984. In addition to the equity in Mangula and Lomagundi, ZMDC also acquired M.T.D. Management Services Ltd., which controlled Bar 20 Mines (Pvt.) Ltd., 85% of Sabi Consolidated Gold Mines, 50% of Jena Mines, and M.T.D. Sanyati (Pvt.) Ltd. Mhangura was to push ahead with development of the Copper Queen and Copper King deposits at Sanyati that had been delayed by former owners because of low copper prices and high electricity costs. Messina already had invested $1 million in developing the Copper Queen deposits when operations were postponed. Ore production at Mhangura's Messina Mine cost $343 per ton of recovered copper in December 1984; at Harper, the cost was $211 per ton, and at Campbell, the cost was $369 per ton of recovered copper. The average production cost for all mines was $257 per ton of recovered copper. The average loss per ton was $134 cumulative through December 1984 for all three mines.

Rio Tinto (Zimbabwe) Ltd.'s Eiffel Flats base metal refinery (56.1% owned by Rio Tinto Zinc) was producing at its targeted operating level of 360 tons of nickel per month and 400 tons of copper per month after it was recommissioned in August. Zimbabwe's two copper refineries, Corsyn Consolidated Mines Ltd.'s Inyati refinery and Mhangura's Alaska refinery, had a combined cathode production capacity of about 25,000 tons per year.

## Table 4.—Estimated production costs at producing copper mines

(January 1985 U.S. dollars per pound of refined copper)

| Country | Number of mines | Mine operating cost | Mill operating cost | Smelter-refinery cost[1] | (Less) byproduct credit | Net operating cost | Taxes[2] | Cash costs | Recovery of capital | Production cost[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 3 | $0.19 | $0.10 | $0.32 | $0.07 | $0.55 | $0.01 | $0.56 | $0.08 | $0.64 |
| Canada | 14 | .27 | .35 | .45 | .32 | .76 | .01 | .77 | .12 | .89 |
| Chile | 9 | .30 | .17 | .11 | .05 | .53 | .02 | .55 | .05 | .60 |
| India | 5 | .34 | .21 | .42 | .03 | .93 | .05 | .98 | .12 | 1.10 |
| Peru | 6 | .19 | .20 | .32 | .05 | .65 | .02 | .67 | .14 | .81 |
| Philippines | 7 | .31 | .27 | .22 | .21 | .58 | .05 | .63 | .07 | .70 |
| South Africa, Republic of | 4 | .41 | .25 | .50 | .49 | .67 | -- | .67 | .13 | .80 |
| United States | 13 | .23 | .20 | .23 | .09 | .56 | .02 | .58 | .12 | .70 |
| Zaire | 7 | .39 | .19 | .25 | .41 | .42 | .08 | .50 | .07 | .57 |
| Zambia | 8 | .31 | .14 | .05 | .09 | .42 | .06 | .48 | .12 | .60 |
| Other | 34 | .25 | .27 | .29 | .30 | .51 | .05 | .56 | .10 | .66 |
| Total or average | 110 | .28 | .21 | .22 | .16 | .55 | .03 | .58 | .09 | .67 |

[1] Includes cost of transportation.
[2] Taxes and production cost are at a zero percent rate of return.

Source: Bureau of Mines, Minerals Availability System (MAS) cost analysis.

### Table 5.—Average ore feed grade and recoverable copper from market economy countries' copper deposits representing nearly 80% of the world reserve base in 1985, by region and country[1]

| Region and country | Number of deposits | Producing | | Nonproducing | | Total | |
|---|---|---|---|---|---|---|---|
| | | Average feed grade[2] (percent) | Recoverable copper[3] (million metric tons) | Average feed grade[2] (percent) | Recoverable copper[3] (million metric tons) | Average feed grade[2] (percent) | Recoverable copper[3] (million metric tons) |
| North America: | | | | | | | |
| Canada | 35 | 0.55 | 9.2 | 0.47 | 8.3 | 0.51 | 17.6 |
| Mexico | 6 | .70 | 15.3 | .60 | 5.2 | .67 | 20.5 |
| United States | 62 | .65 | 27.4 | .60 | 30.0 | .62 | 57.4 |
| Total or average | 103 | .64 | 51.9 | .57 | 43.5 | .61 | 95.5 |
| Central and South America: | | | | | | | |
| Argentina | 3 | -- | -- | .55 | 6.6 | .55 | 6.6 |
| Chile | 16 | 1.02 | 85.3 | 1.04 | 26.9 | 1.03 | 112.2 |
| Peru | 12 | .82 | 10.2 | .82 | 11.1 | .82 | 21.2 |
| Other | 5 | 1.03 | 1.4 | .72 | 9.3 | .75 | 10.7 |
| Total[4] or average | 36 | 1.00 | 96.8 | .84 | 53.9 | .93 | 150.7 |
| Europe | 12 | .58 | 4.0 | W | W | W | 5.5 |
| Middle East | 10 | 1.17 | 4.8 | 1.88 | 1.5 | 1.30 | 6.3 |
| Asia: | | | | | | | |
| India | 6 | 1.24 | 4.6 | W | W | W | 4.7 |
| Philippines | 22 | .44 | 4.0 | .50 | 6.4 | .47 | 10.4 |
| Other | 6 | 1.21 | 1.9 | W | W | W | 2.9 |
| Total[4] or average | 34 | .72 | 10.5 | .47 | 7.5 | .59 | 18.0 |
| Africa: | | | | | | | |
| South Africa, Republic of | 5 | .62 | 1.7 | W | W | W | W |
| Zaire | 8 | 3.93 | 17.8 | W | W | W | W |
| Zambia | 9 | 2.31 | 10.0 | W | W | W | W |
| Other | 10 | 1.62 | .8 | 2.21 | .9 | 1.87 | 1.7 |
| Total[4] or average | 32 | 2.51 | 30.3 | 2.57 | 4.4 | 2.51 | 34.7 |
| Oceania: | | | | | | | |
| Australia | 9 | 2.82 | 3.9 | 1.59 | 21.7 | 1.69 | 25.5 |
| Other | 5 | .47 | 6.5 | .47 | 5.9 | .47 | 12.4 |
| Total[4] or average | 14 | .67 | 10.5 | 1.05 | 27.5 | .91 | 37.9 |
| Grand total[4] or average | 241 | .91 | 208.7 | .75 | 139.9 | .87 | [5]348.6 |

W Withheld to avoid disclosing company proprietary data; included in "Total or average."

[1] Based on Jan. 1985 resource estimates for 110 producing and 131 idle, developing, or explored deposits in market economy countries. Excludes copper available from byproduct mines. Total world reserve base is estimated at 566 million tons contained copper in ore.

[2] Feed grade to concentrator, averaged over the life of the mine. Does not include leach material.

[3] Includes recoverable copper from leach operations.

[4] Data may not add to totals shown because of independent rounding.

[5] Recoverable total corresponds to 465 million tons contained copper in ore, or 78.8% of the world reserve base for copper.

Source: Bureau of Mines, Minerals Availability System (MAS).

## TECHNOLOGY

A copper-tungsten composite substrate for microcircuits, which combined copper's good thermal conductivity and tungsten's low thermal expansion, was developed and marketed by Sumitomo Electric Industries Ltd. The new composite was produced by sintering a mixture of copper and tungsten powder. Beryllium copper was used in similar applications, but presented a problem of toxicity.[64]

Electromagnetic forces that result when eddy currents are induced in a molten metal load were used to contain and shape molten metal during copper alloy casting in place of the conventional chilled metal mold. The development of this technology, undertaken by Olin Corp., was described in a paper highlighting the commercial benefits.[65] This casting technique eliminated the mold-related defects normally encountered in direct chill mold-casting, and provided copper alloy castings with greatly improved hot workability.

Bureau of Mines studies of the flotation behavior of a series of minerals containing varying amounts of copper and iron illustrated that the percentage of iron in the mineral significantly affected both the potential at which the mineral floats and the mechanism by which the collector, ethylxanthate, interacted with the mineral. Current research in froth flotation research was being directed toward gaining a fundamental understanding of sulfide flotation chemistry to improve existing flotation methods, devise new methods, and help in the selection of control parameters for computerized process control of flotation circuits.[66]

Mineral liberation research at the Bureau of Mines was directed toward devising methods for optimizing and predicting liberation of mineral phases during the grinding of complex ores. The cobalt mineral siegenite is closely associated with the copper mineral chalcopyrite in ores of the Missouri Lead Belt. Liberation of the two minerals required to recover a cobalt preduct and the influence of an organic polymer in ball-mill grinding of copper, dolomite, and quartz ore was the subject of a Bureau of Mines report.[67] The degree of mineral liberation and the particle size distribution of ground products were measured using optical and scanning electron microscopy in conjunction with computerized image analysis techniques.

Heap and dump leaching are among the simplest and least expensive methods for leaching metal values from ores containing copper, gold, silver, or uranium. However, the reactions may be slow and metal recoveries can be low. Bureau of Mines research was being directed toward gaining a fundamental understanding of leaching chemistry, both to improve existing methods and to devise new methods for faster, more complete extraction. Several Bureau papers were published during the year on various aspects of this research.[68]

Magma reached an agreement with M.I.M. Holdings to utilize copper refinery technology developed by the Australian company, known as the "Isa Process," at the new oxide copper plant under construction at the San Manuel copper property. The key feature of the process is the use of permanent stainless steel cathode plates. The process gives substantial energy savings and other operational advantages over the older conventional technology. This would be the first time it was tried in an electrowinning process, however. Magma was also instituting its own patented process to retain tankhouse fumes during the refining process.

An in situ bioleach pilot operation to recover copper from an abandoned underground mine in northern Italy was started up at the beginning of the year by the University of Cagliari, with funding from the Italian National Research Council and the Ministry of Public Education. Indigenous bacteria in acidic mine waters were being used to leach copper from the mixed pyrite-chalcopyrite ore, then the copper was recovered from solution by conventional cementation. Copper production from the ore containing 1% to 2% copper was about 3 kilograms per hour. Filamentous fungi were also being used to recover copper in work done in the United Kingdom. *Penicillium spinulosum, Aspergillus niger,* and *Trichoderma viride* were being used to remove copper and gold from aqueous effluents.[69] Research was being done at Michigan Technical Institute on the use of the bacteria *Thiobacillus ferrooxidans* in extracting copper from the White Pine copper ores.[70]

Direct smelting of partially roasted copper concentrates to blister copper by using residual sulfide as a reductant was reviewed.[71] Roasting and smelting chemistries were discussed in light of experimental results and commercial process control requirements. Until now, significant copper losses to the slag, as well as intolerably high antimony, arsenic, and bismuth impurity levels in the copper, have impeded the progress of direct smelting. Effective solutions to these problems were outlined that could result in elimination of the converter vessel from the process.

A new continuous process for conversion of copper mattes to blister copper was successfully pilot-tested and was ready for commercial application. The process, known as "Kennecott-Outokumpu Flash Converting," involved reaction of solidified matte particles with industrial-grade oxygen in a flash furnace to produce blister copper and a small quantity of slag that could be recycled to the primary smelting furnace. Reduced smelter capital and operating costs were major benefits of the process.[72]

The economics of the Oxygen Sprinkle Smelting (OSS) process were examined, and its capital and operating costs were compared with the Outokumpu and Inco processes for the retrofitting of conventional reverberatory smelters to modern oxygen flash smelting. The current economic return on investment makes it difficult to justify building new greenfield smelters. On the other hand, it was reported that much can be gained by modernizing existing plants such as retrofitting conventional reverberatory/Peirce-Smith converter-type smelters. Benefits, such as increased throughput, lower energy consumption, higher metal recovery, and a viable means for environmental control were said to be realized with less capital outlay.[73]

The simultaneous recovery of various metals from complex sulfide ores accomplished in a single smelting process was being developed at the University of Birmingham, England, and supported by five multinational companies through the Mineral Industry Research Organization and the British Technology Group of London.[74] The technique promised to be an economical way to deal with ores that are difficult and expensive to process by conventional methods. A 5-ton-per-day demonstration unit was expected to start in 1986. In the process, a bulk concentrate was prepared and fed into a two-stage smelter. The concentrates were melted under nonoxidizing conditions in the first furnace. At slightly higher temperatures, oxygen was added in the second furnace to react with sulfur in the matte, forming sulfur dioxide and freeing the metals. Most of the copper settled to the bottom where at this point it was removed. Unreacted matte was recirculated in a continuous closed loop from the second hearth to the first.

EPA research indicated a less costly approach for sulfur removal from stack gases. The method, dubbed "E-SOx," was said to be 20% cheaper than current methods per ton of sulfur removed.[75] Developed by EPA's Air and Energy Engineering Research Laboratory, E-SOx substitutes multistage electrostatic precipitators (ESP) for single-stage units in retrofits. ESP's take up about one-third less space and the reclaimed space can then be used for scrubbing or spray-drying operations to remove sulfur from the flue gas, eliminating the need for a separate processing unit.

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## Table 6.—Percentage of copper ore and recoverable copper extracted from open pit and underground mines in the United States

| Year | Open pit | | Underground | |
|---|---|---|---|---|
| | Ore | Copper[1] | Ore | Copper[2] |
| 1981 | 89 | 84 | 11 | 16 |
| 1982 | 88 | 82 | 12 | 18 |
| 1983 | 89 | 85 | 11 | 15 |
| 1984 | 92 | 87 | 8 | 13 |
| 1985 | 88 | 89 | 12 | 11 |

[1] Includes copper from dump leaching.

[2] Includes copper from in-place leaching and copper recovered from tailings and as a byproduct from other sources.

## Table 7.—Mine production of recoverable copper in the United States, by month and by State

(Metric tons)

| | 1981 | 1982 | 1983 | 1984[r] | 1985 |
|---|---|---|---|---|---|
| Month: | | | | | |
| January | 123,244 | 113,150 | 90,025 | 92,971 | 92,699 |
| February | 117,620 | 108,134 | 77,664 | 87,863 | 87,089 |
| March | 127,559 | 120,578 | 89,274 | 96,124 | 100,170 |
| April | 127,251 | 112,662 | 84,646 | 91,250 | 93,641 |
| May | 130,953 | 97,628 | 92,170 | 95,045 | 96,834 |
| June | 127,188 | 90,614 | 89,717 | 98,000 | 90,225 |
| July | 123,726 | 85,179 | 76,323 | 88,235 | 90,711 |
| August | 136,221 | 81,574 | 79,211 | 89,032 | 87,446 |
| September | 134,731 | 78,585 | 86,704 | 88,074 | 81,898 |
| October | 140,771 | 87,071 | 89,608 | 94,382 | 94,222 |
| November | 134,944 | 90,285 | 93,706 | 92,507 | 91,870 |
| December | 113,952 | 81,515 | 89,050 | 89,130 | 98,953 |
| Total | 1,538,160 | 1,146,975 | 1,038,098 | 1,102,613 | 1,105,758 |
| State: | | | | | |
| Alaska | -- | W | W | -- | -- |
| Arizona | 1,040,813 | 769,521 | 678,216 | 746,453 | 796,556 |
| California | W | W | W | W | W |
| Colorado | W | 575 | W | W | W |
| Idaho | 4,245 | 3,074 | 3,556 | 3,701 | 3,551 |
| Illinois | -- | -- | -- | -- | W |
| Michigan | W | W | -- | -- | W |
| Missouri | 8,411 | 7,941 | 7,725 | 5,818 | 13,410 |
| Montana | 62,485 | 64,951 | 33,337 | W | 15,092 |

See footnotes at end of table.

## Table 7.—Mine production of recoverable copper in the United States, by month and by State —Continued

(Metric tons)

| | 1981 | 1982 | 1983 | 1984^r | 1985 |
|---|---|---|---|---|---|
| State —Continued | | | | | |
| Nevada | W | W | W | W | W |
| New Mexico | 154,114 | W | W | W | W |
| Oregon | W | -- | W | -- | -- |
| South Carolina | W | -- | -- | -- | -- |
| Tennessee | W | W | W | W | W |
| Utah | 211,276 | 189,090 | 169,751 | W | W |
| Washington | W | W | -- | -- | -- |
| Total | 1,538,160 | 1,146,975 | 1,038,098 | 1,102,613 | 1,105,758 |

^r Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

## Table 8.—Twenty-five leading copper-producing mines in the United States in 1985, in order of output

| Rank | Mine | County and State | Operator | Source of copper |
|---|---|---|---|---|
| 1 | Morenci | Greenlee, AZ | Phelps Dodge Corp | Copper-molybdenum ore, concentrated and leached. |
| 2 | Tyrone | Grant, NM | Phelps Dodge Corp. and Burro Chief Copper Co. | Copper ore, concentrated and leached. |
| 3 | Chino | do | Chino Mines Co | Copper-molybdenum ore, concentrated and leached. |
| 4 | Sierrita | Pima, AZ | Duval Corp | Copper molybdenum ore, concentrated. |
| 5 | San Manuel | Pinal, AZ | Magma Copper Co | Copper-molybdenum ore and retreated slag, concentrated. |
| 6 | Ray | do | Kennecott | Copper ore, concentrated and leached. |
| 7 | Bagdad | Yavapai, AZ | Cyprus Bagdad Copper Co | Copper-molybdenum ore, concentrated and leached. |
| 8 | Pinto Valley | Gila, AZ | Pinto Valley Copper Corp | Do. |
| 9 | Inspiration | do | Inspiration Consolidated Copper Co. | Do. |
| 10 | Eisenhower | Pima, AZ | ASARCO Incorporated | Copper ore, concentrated. |
| 11 | Bingham Canyon | Salt Lake, UT | Kennecott | Copper-molybdenum ore, concentrated and leached. |
| 12 | Troy | Lincoln, MT | ASARCO Incorporated | Silver-copper ore, concentrated. |
| 13 | Twin Buttes | Pima, AZ | Anamax Mining Co | Copper ore, leached. |
| 14 | Copperhill | Polk, TN | Tennessee Chemical Co | Copper-zinc-iron sulfide ore, concentrated. |
| 15 | Lakeshore | Pinal, AZ | Noranda Lakeshore Mines Inc | Copper ore, leached. |
| 16 | Casteel | Iron, MO | St. Joe Minerals Corp | Lead-copper ore, concentrated. |
| 17 | San Xavier | Pima, AZ | ASARCO Incorporated | Copper ore, concentrated. |
| 18 | Esperanza | do | Duval Corp | Copper ore, leached. |
| 19 | Silver Bell | do | ASARCO Incorporated | Do. |
| 20 | Miami | Gila, AZ | Pinto Valley Copper Corp | Do. |
| 21 | Mission | Pima, AZ | ASARCO Incorporated | Copper ore, concentrated. |
| 22 | Battle Mountain | Lander, NV | Battle Mountain Gold Co | Copper ore, leached. |
| 23 | Johnson | Cochise, AZ | Cyprus Johnson Copper Co | Do. |
| 24 | Buick | Iron, MO | AMAX Lead Co. of Missouri | Lead-zinc ore, concentrated. |
| 25 | Copper Queen | Cochise, AZ | Phelps Dodge Corp | Copper ore, leached. |

### Table 9.—Mine production of copper-bearing ores and recoverable copper content of ores produced in the United States, by source and treatment process

(Metric tons)

| Source and treatment process | 1981 |  | 1982 |  | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Gross weight | Recoverable copper | Gross weight | Recoverable copper | Gross weight | Recoverable copper | Gross weight | Recoverable copper | Gross weight | Recoverable copper |
| Mined copper ore: |  |  |  |  |  |  |  |  |  |  |
| Concentrated[1] | 263,144,000 | 1,275,999 | 174,537,000 | 883,153 | 171,776,000 | 810,090 | 168,226,000 | 883,338 | 160,258,000 | 906,438 |
| Leached[2] | 14,372,000 | [3]131,400 | 7,289,000 | 123,848 | 6,154,000 | 104,991 | 3,588,000 | 106,597 | 1,952,000 | 98,453 |
| Total | 277,516,000 | 1,407,399 | 181,826,000 | 1,007,001 | 177,930,000 | 915,081 | 171,814,000 | [r]989,935 | 162,210,000 | 1,004,891 |
| Copper precipitates shipped; leached from tailings, dump, and in-place material | 170,604 | 113,991 | 147,701 | 104,791 | 130,857 | 89,274 | 120,437 | 80,845 | 118,096 | 82,948 |
| Miscellaneous: |  |  |  |  |  |  |  |  |  |  |
| Silver ore | 1,713,000 | 6,258 | 3,652,000 | 20,616 | 4,483,000 | 19,384 | 4,487,000 | 22,334 | 1,041,000 | 3,745 |
| Lead ore | 7,729,000 | 8,411 | 8,531,000 | 7,941 | 7,303,000 | 7,725 | 4,748,000 | 5,818 | 6,433,000 | 13,410 |
| Other copper-bearing ores[4] | 3,946,000 | 2,101 | 6,535,000 | 6,626 | 9,970,000 | 6,634 | 22,821,000 | 3,681 | 8,898,000 | 764 |
| Grand total | XX | 1,538,160 | XX | 1,146,975 | XX | 1,038,098 | XX | [r]1,102,613 | XX | 1,105,758 |

[r] Revised. XX Not applicable.

[1] Includes the following methods of concentration: dual process (concentration followed by leaching), leach-precipitation-flotation, and froth flotation.

[2] At least 85% of leached ore processed by electrowinning.

[3] Includes some copper electrowon from in-place leaching.

[4] Includes gold ore, gold-silver ore, lead-zinc ore, molybdenum ore, tungsten ore, flux ores, cleanup, and tailings.

### Table 10.—Recoverable copper, gold, and silver content of concentrated copper ore in 1985

| State | Ore concentrated (thousand metric tons) | Recoverable metal content | | | | Value of gold and silver per metric ton of ore |
|---|---|---|---|---|---|---|
| | | Copper | | Gold (troy ounces) | Silver (troy ounces) | |
| | | Metric tons | Percent | | | |
| Arizona | 124,889 | 678,937 | 0.54 | 46,056 | 4,382,491 | $0.33 |
| Michigan | W | W | W | -- | W | W |
| Montana | 2,579 | 14,936 | .57 | W | 3,565,927 | W |
| New Mexico | W | W | W | W | W | W |
| Tennessee | W | W | W | -- | W | W |
| Utah | W | W | W | W | W | W |
| Total or average | 160,258 | 906,438 | .56 | 74,633 | 9,658,981 | .51 |

W Withheld to avoid disclosing company proprietary data; included in "Total or average."

### Table 11.—Blister and anode copper produced in the United States, by source of material

(Metric tons)

| Source | 1981 | 1982 | 1983 | 1984[r] | 1985 |
|---|---|---|---|---|---|
| Ores and concentrates: | | | | | |
| Domestic | 1,294,962 | 940,547 | 888,130 | 989,924 | 941,575 |
| Foreign | 21,794 | 35,148 | 39,609 | 24,200 | 1,882 |
| Secondary materials[1] | 60,882 | 45,105 | 59,276 | 169,296 | 249,890 |
| Total | 1,377,638 | 1,020,800 | 987,015 | 1,183,420 | 1,193,347 |

[r] Revised.

[1] Production from secondary sources prior to 1984 excludes data for those plants that were not associated with refineries processing primary materials.

### Table 12.—Primary and secondary copper produced by refineries and electrowinning plants in the United States

(Metric tons)

| | 1981 | 1982 | 1983 | 1984[r] | 1985 |
|---|---|---|---|---|---|
| PRIMARY | | | | | |
| Electrolytic | [r]1,297,353 | [r]1,039,772 | [r]959,801 | 978,999 | [1]947,559 |
| Electrowon | 161,083 | 131,858 | [r]126,659 | 127,286 | 109,606 |
| Fire-refined | [r]85,581 | [r]55,148 | [r]95,630 | 58,315 | W |
| Total | 1,544,017 | 1,226,778 | 1,182,090 | 1,164,600 | 1,057,165 |
| SECONDARY | | | | | |
| Electrolytic | [2]303,338 | [2]268,952 | [r] [2]224,761 | 186,712 | 264,834 |
| Fire-refined | [3]179,499 | [3]198,597 | [3]176,907 | 138,237 | 114,347 |
| Total | [r]482,837 | [r]467,549 | [r]401,668 | 324,949 | 379,181 |
| Grand total | [r]2,026,854 | [r]1,694,327 | [r]1,583,758 | 1,489,549 | 1,436,346 |
| Primary domestic materials[4] | [r]1,419,189 | [r]1,050,445 | [r]1,028,423 | 1,089,584 | 1,003,636 |
| Primary foreign materials[4] | [r]124,828 | [r]176,333 | [r]153,667 | 75,016 | 53,529 |
| Secondary materials | [r]482,837 | [r]467,549 | [r]401,668 | 324,949 | 379,181 |
| Total | [r]2,026,854 | [r]1,694,327 | [r]1,583,758 | 1,489,549 | 1,436,346 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Electrolytic."

[1] Includes fire-refined copper amounting to less than 2% of total primary production.

[2] Includes some copper fire-refined at plants processing primary materials.

[3] Includes some copper electrolytically refined at plants processing secondary materials only.

[4] The separation of refined copper into metal of domestic and foreign origins can only be approximated at this stage of processing.

## Table 13.—Copper cast in forms at refineries in the United States

(Thousand metric tons)

| | 1984[r] | 1985 |
|---|---|---|
| Billets | 94 | 94 |
| Cakes | 15 | 7 |
| Cathodes | 1,276 | 1,280 |
| Ingots and ingot bars | 52 | -- |
| Wirebars | 38 | 50 |
| Other forms | 15 | 5 |
| Total | 1,490 | 1,436 |

[r] Revised.

## Table 14.—Production, shipments, and stocks of copper sulfate in the United States

(Metric tons)

| Year | Production | | Shipments[1] | Stocks, Dec. 31 |
|---|---|---|---|---|
| | Quantity | Copper content | | |
| 1981 | 35,636 | 9,413 | 36,103 | 5,269 |
| 1982 | 32,227 | 8,385 | 33,355 | 4,142 |
| 1983 | 37,500 | 9,789 | 36,614 | 5,029 |
| 1984[r] | 34,859 | 8,862 | 37,006 | 3,564 |
| 1985 | 32,740 | 8,265 | 31,952 | 4,353 |

[r] Revised.

[1] Includes consumption by producing companies.

## Table 15.—Byproduct sulfuric acid[1] (100% basis) produced in the United States

(Metric tons)

| Plant type | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Copper[2] | 2,593,762 | 1,879,983 | 1,837,827 | 2,251,312 | 2,230,257 |
| Lead[3] | 405,974 | 310,606 | 319,187 | 248,474 | 267,159 |
| Zinc[4] | 545,890 | 341,728 | 384,529 | 442,517 | 430,946 |
| Total | 3,545,626 | 2,532,317 | 2,541,493 | 2,942,303 | 2,928,362 |

[1] Includes acid from foreign materials.

[2] Excludes acid made from pyrite concentrates.

[3] Includes acid processed at molybdenum plants to avoid disclosing company proprietary data.

[4] Excludes acid made from native sulfur.

### Table 16.—Copper recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Metric tons)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| KIND OF SCRAP | | | | | |
| New scrap: | | | | | |
| Copper-base | [r]793,115 | 649,406 | 611,890 | [r]637,201 | 633,924 |
| Aluminum-base | 22,281 | 20,192 | 21,926 | 21,919 | 13,330 |
| Nickel-base | 162 | 122 | 254 | 68 | 321 |
| Zinc-base | 34 | 20 | 31 | 31 | 35 |
| Total | [r]815,592 | 669,740 | 634,101 | [r]659,219 | 647,610 |
| Old scrap: | | | | | |
| Copper-base | [r]576,497 | 501,576 | 431,243 | [r]443,585 | 486,500 |
| Aluminum-base | 15,043 | 16,047 | 18,015 | 16,929 | 15,459 |
| Nickel-base | 123 | 76 | 158 | 102 | 676 |
| Zinc-base | 142 | 27 | 62 | 79 | 60 |
| Total | [r]591,805 | 517,726 | 449,478 | [r]460,695 | 502,695 |
| Grand total | [r]1,407,397 | 1,187,466 | 1,083,579 | [r]1,119,914 | 1,150,305 |
| FORM OF RECOVERY | | | | | |
| As unalloyed copper: | | | | | |
| At electrolytic plants | [r]303,338 | 268,952 | 224,761 | [r]186,712 | 264,834 |
| At other plants | 200,465 | 212,613 | 194,093 | [r]151,477 | 124,488 |
| Total | [r]503,803 | 481,565 | 418,854 | [r]338,189 | 389,322 |
| In brass and bronze | 850,546 | 660,152 | 625,349 | [r]735,154 | 724,273 |
| In alloy iron and steel | 1,876 | 1,492 | 1,434 | [r]1,705 | 1,336 |
| In aluminum alloys | 47,728 | 41,930 | 36,704 | [r]43,511 | 33,398 |
| In other alloys | 217 | 77 | 162 | [r]307 | 1,118 |
| In chemical compounds | 3,227 | 2,250 | 1,076 | 1,048 | 858 |
| Total | 903,594 | 705,901 | 664,725 | [r]781,725 | 760,983 |
| Grand total | [r]1,407,397 | 1,187,466 | 1,083,579 | [r]1,119,914 | 1,150,305 |

[r] Revised.

### Table 17.—Copper recovered as refined copper and in alloys and other forms from copper-base scrap processed in the United States, by type of operation

(Metric tons)

| Type of operation | From new scrap | | From old scrap | | Total | |
|---|---|---|---|---|---|---|
| | 1984[r] | 1985 | 1984 | 1985 | 1984[r] | 1985 |
| Ingot makers and secondary smelters | 72,910 | 65,823 | [r]258,583 | 248,948 | 331,493 | 314,771 |
| Electrolytic-refiners | 30,276 | 75,979 | [r]130,926 | 188,855 | 161,202 | 264,834 |
| Brass mills | 513,801 | 477,517 | 15,790 | 16,121 | 529,591 | 493,638 |
| Foundries and manufacturers | 19,867 | 13,750 | [r]37,585 | 32,573 | 57,452 | 46,323 |
| Chemical plants | 347 | 855 | [r]701 | 3 | 1,048 | 858 |
| Total | 637,201 | 633,924 | [r]443,585 | 486,500 | 1,080,786 | 1,120,424 |

[r] Revised.

## Table 18.—Production of secondary copper and copper-alloy products in the United States, by item produced from scrap

(Metric tons)

| Item produced from scrap | 1984[r] | 1985 |
|---|---|---|
| UNALLOYED COPPER PRODUCTS | | |
| Electrolytically refined copper | 186,712 | 264,834 |
| Fire-refined copper | 138,237 | 114,347 |
| Copper powder | 12,783 | 9,776 |
| Copper castings | 457 | 365 |
| Total | 338,189 | 389,322 |
| ALLOYED COPPER PRODUCTS | | |
| Brass and bronze ingots: | | |
| Tin bronzes | 16,075 | 17,907 |
| Leaded red brass and semired brass | 116,569 | 106,877 |
| High-leaded tin bronze | 12,716 | 8,335 |
| Yellow brass | 11,004 | 8,575 |
| Manganese bronze | 8,062 | 8,069 |
| Aluminum bronze | 8,331 | 7,523 |
| Nickel silver | 3,514 | 2,931 |
| Silicon bronze and brass | 4,526 | 4,276 |
| Copper-base hardeners and master alloys | 15,931 | 13,274 |
| Miscellaneous | 313 | 2,898 |
| Total | 197,041 | 180,665 |
| Brass-mill products | 666,640 | 562,324 |
| Brass and bronze castings | 41,977 | 31,332 |
| Brass powder | 879 | 396 |
| Copper in chemical products | 1,048 | 858 |
| Grand total | 1,245,774 | 1,164,897 |

[r] Revised.

## Table 19.—Composition of secondary copper-alloy production in the United States

(Metric tons)

| | Copper | Tin | Lead | Zinc | Nickel | Aluminum | Total |
|---|---|---|---|---|---|---|---|
| Brass and bronze ingot production:[1] | | | | | | | |
| 1984[r] | 156,476 | 7,560 | 12,294 | 20,456 | 236 | 19 | 197,041 |
| 1985 | 148,204 | 6,585 | 9,997 | 15,681 | 183 | 15 | 180,665 |
| Secondary metal content of brass mill products: | | | | | | | |
| 1984[r] | 531,765 | 456 | 3,733 | 127,847 | 2,823 | 16 | 666,640 |
| 1985 | 454,853 | 220 | 2,712 | 102,580 | 1,944 | 15 | 562,324 |
| Secondary metal content of brass and bronze castings: | | | | | | | |
| 1984[r] | 34,541 | 1,115 | 2,181 | 4,069 | 16 | 55 | 41,977 |
| 1985 | 26,408 | 784 | 1,448 | 2,614 | 22 | 56 | 31,332 |

[r] Revised.

[1] About 94% from scrap and 6% from other than scrap in 1984 (revised) and in 1985.

## Table 20.—Stocks and consumption of purchased copper scrap in the United States in 1985, by class of consumer and type of scrap

(Metric tons, gross weight)

| Class of consumer and type of scrap | Stocks, Jan. 1 | Receipts | Consumption | | | Stocks, Dec. 31 |
|---|---|---|---|---|---|---|
| | | | New scrap | Old scrap | Total | |
| SECONDARY SMELTERS-REFINERS | | | | | | |
| No. 1 wire and heavy | 6,597 | 134,853 | 31,307 | 97,670 | 128,977 | 12,473 |
| No. 2 wire, mixed heavy and light | 14,897 | 223,999 | 41,615 | 167,025 | 208,640 | 30,256 |
| Composition or soft red brass | 2,797 | 42,208 | 8,517 | 33,989 | 42,506 | 2,499 |
| Railroad-car boxes | 253 | 1,123 | -- | 1,249 | 1,249 | 127 |
| Yellow brass | 5,810 | 58,835 | 30,889 | 29,369 | 60,258 | 4,387 |
| Cartridge cases | 12 | 245 | -- | 237 | 237 | 20 |
| Automobile radiators (unsweated) | 4,396 | 72,248 | 2,606 | 70,959 | 73,565 | 3,079 |
| Bronze | 1,745 | 15,620 | 2,418 | 13,405 | 15,823 | 1,542 |
| Nickel silver and cupronickel | 796 | 1,701 | 707 | 1,375 | 2,082 | 415 |
| Low brass | 640 | 1,734 | 571 | 828 | 1,399 | 975 |
| Aluminum bronze | 94 | 168 | 94 | 65 | 159 | 103 |
| Refinery brass | 14,660 | 86,568 | 25,080 | 64,819 | 89,899 | 11,329 |
| Low-grade scrap and residues | 21,001 | 108,184 | 75,896 | 35,344 | 111,240 | 17,945 |
| Total | 73,698 | 747,486 | 219,700 | 516,334 | 736,034 | 85,150 |
| BRASS MILLS[1] | | | | | | |
| No. 1 wire and heavy | 8,508 | 193,265 | 180,439 | 12,826 | 193,265 | 9,124 |
| No. 2 wire, mixed heavy and light | 3,591 | 65,311 | 63,971 | 1,340 | 65,311 | 1,047 |
| Yellow brass | 18,730 | 265,820 | 263,678 | 2,142 | 265,820 | 10,849 |
| Cartridge cases and brass | 9,802 | 66,984 | 66,338 | 646 | 66,984 | 7,184 |
| Bronze | 1,248 | 3,517 | 3,517 | -- | 3,517 | 2,277 |
| Nickel silver and cupronickel | 4,214 | 13,565 | 13,254 | 311 | 13,565 | 4,155 |
| Low brass | 2,813 | 12,524 | 12,431 | 93 | 12,524 | 1,945 |
| Aluminum bronze | -- | 37 | 37 | -- | 37 | -- |
| Total | 48,906 | 621,023 | 603,665 | 17,358 | 621,023 | 36,581 |
| FOUNDRIES, CHEMICAL PLANTS, AND OTHER MANUFACTURERS | | | | | | |
| No. 1 wire and heavy | 1,935 | 25,984 | 6,582 | 19,263 | 25,845 | 2,074 |
| No. 2 wire, mixed heavy and light | 608 | 3,820 | 1,143 | 2,953 | 4,096 | 332 |
| Composition or soft red brass | 406 | 8,939 | 4,715 | 4,202 | 8,917 | 428 |
| Railroad-car boxes | 1,507 | 2,502 | -- | 3,524 | 3,524 | 485 |
| Yellow brass | 595 | 5,965 | 4,044 | 2,021 | 6,065 | 495 |
| Automobile radiators (unsweated) | 933 | 3,689 | 56 | 3,609 | 3,665 | 957 |
| Bronze | 851 | 636 | 207 | 447 | 654 | 833 |
| Nickel silver and cupronickel | 27 | 162 | 67 | 105 | 172 | 17 |
| Low brass | 50 | 995 | 666 | 342 | 1,008 | 37 |
| Aluminum bronze | 103 | 707 | 11 | 762 | 773 | 37 |
| Low-grade scrap and residues | -- | 3 | -- | 3 | 3 | -- |
| Total[2] | 7,015 | 53,402 | 17,491 | 37,231 | 54,722 | 5,695 |
| GRAND TOTAL | | | | | | |
| No. 1 wire and heavy | 17,040 | 354,102 | 218,328 | 129,759 | 348,087 | 23,671 |
| No. 2 wire, mixed heavy and light | 19,096 | 293,130 | 106,729 | 171,318 | 278,047 | 31,635 |
| Composition or soft red brass | 3,203 | 51,147 | 13,232 | 38,191 | 51,423 | 2,927 |
| Railroad-car boxes | 1,760 | 3,625 | -- | 4,773 | 4,773 | 612 |
| Yellow brass | 25,135 | 330,620 | 298,611 | 33,532 | 332,143 | 15,731 |
| Cartridge cases | 9,814 | 67,229 | 66,338 | 883 | 67,221 | 7,204 |
| Automobile radiators (unsweated) | 5,329 | 75,937 | 2,662 | 74,568 | 77,230 | 4,036 |
| Bronze | 3,844 | 19,773 | 6,142 | 13,852 | 19,994 | 4,652 |
| Nickel silver and cupronickel | 5,037 | 15,428 | 14,028 | 1,791 | 15,819 | 4,587 |
| Low brass | 3,503 | 15,253 | 13,668 | 1,263 | 14,931 | 2,957 |
| Aluminum bronze | 197 | 912 | 142 | 827 | 969 | 140 |
| Low-grade scrap and residues[3] | 35,661 | 194,755 | 100,976 | 100,166 | 201,142 | 29,274 |
| Total | 129,619 | 1,421,911 | 840,856 | 570,928 | 1,411,779 | 127,426 |

[1] Brass-mill stocks include home scrap; purchased scrap consumption is assumed equal to receipts, so lines in "BRASS MILLS" and "GRAND TOTAL" sections do not balance.

[2] Of the totals shown, chemical plants reported the following: unalloyed copper scrap, 891 tons new and 3 tons old.

[3] Includes refinery brass.

## Table 21.—Consumption of copper and brass materials in the United States, by item

(Metric tons)

| Item | Brass mills | Wire rod mills | Foundries, chemical plants, miscellaneous users | Secondary smelters-refiners | Total |
|---|---|---|---|---|---|
| 1984: | | | | | |
| Copper scrap | 675,472 | -- | [r]69,484 | [r]758,107 | [r]1,503,063 |
| Refined copper[r] [1] | 576,160 | 1,504,694 | 34,981 | 6,897 | 2,122,732 |
| Brass ingot | 16,553 | -- | [r]135,364 | -- | [r]151,917 |
| Slab zinc[r] | 116,392 | -- | 3,689 | 5,268 | 125,349 |
| Miscellaneous | -- | -- | -- | [r]3,365 | [r]3,365 |
| 1985: | | | | | |
| Copper scrap | 621,023 | -- | 54,722 | 736,034 | 1,411,779 |
| Refined copper[1] | 485,343 | 1,378,586 | 36,406 | 5,299 | 1,905,634 |
| Brass ingot | 13,289 | -- | 131,186 | -- | 144,475 |
| Slab zinc | 69,052 | -- | 4,693 | 4,175 | 77,920 |
| Miscellaneous | -- | -- | -- | 6,090 | 6,090 |

[r] Revised.

[1] Detailed information on consumption of refined copper can be found in table 24.

## Table 22.—Apparent consumption of copper in the United States

(Metric tons)

| Period | Refined copper production | Total old scrap | Net refined imports | Stock change during period | Apparent consumption |
|---|---|---|---|---|---|
| 1981 | 1,544,017 | [r]591,805 | 306,228 | 171,000 | [r]2,271,050 |
| 1982 | 1,226,778 | 517,726 | 227,881 | 211,000 | [r]1,761,385 |
| 1983 | 1,182,090 | 449,478 | 378,171 | -4,000 | [r]2,013,739 |
| 1984 | [r]1,164,600 | [r]460,695 | 353,285 | -128,000 | [r]2,106,580 |
| 1985: | | | | | |
| January | 96,071 | 38,936 | 40,288 | -35,000 | 210,295 |
| February | 82,603 | 41,006 | 15,824 | -52,000 | 191,433 |
| March | 94,878 | 50,093 | 23,719 | -24,000 | 192,690 |
| April | 95,411 | 43,882 | 19,383 | -39,000 | 197,676 |
| May | 101,555 | 46,112 | 16,944 | -48,000 | 212,611 |
| June | 77,170 | 43,979 | 38,856 | -1,000 | 161,005 |
| July | 90,880 | 38,964 | 22,627 | 12,000 | 140,471 |
| August | 84,716 | 38,270 | 20,039 | -12,000 | 155,025 |
| September | 81,873 | 45,146 | 32,793 | -10,000 | 169,812 |
| October | 84,901 | 40,367 | 18,509 | -25,000 | 168,777 |
| November | 79,490 | 39,132 | 42,224 | -14,000 | 174,846 |
| December | 87,617 | 36,808 | 48,582 | -5,000 | 178,007 |
| Total | 1,057,165 | 502,695 | 339,788 | -253,000 | 2,152,648 |

[r] Revised.

### Table 23.—Foundries and miscellaneous manufacturers consumption of brass ingot and refined copper and copper scrap in the United States, by geographic division and State

(Metric tons)

| Geographic division and State | Tin bronzes | Leaded red brass and semi-red brass | Yellow brass | Man-ganese bronze | Hardeners and master alloys | Nickel silver | Alumi-num bronze | Total brass ingot | Refined copper con-sumed | Copper scrap con-sumed |
|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | 28,885 | 94,142 | 19,659 | 6,270 | 4,411 | 2,030 | 6,853 | 162,250 | 33,533 | 73,038 |
| 1982 | 24,577 | 75,402 | 12,584 | 5,220 | 2,499 | 1,619 | 5,038 | 126,939 | $^{r}$28,812 | $^{r}$57,992 |
| 1983 | $^{r}$24,448 | $^{r}$80,741 | $^{r}$11,155 | 5,423 | $^{r}$2,511 | $^{r}$1,612 | 5,675 | $^{r}$131,565 | $^{r}$30,050 | $^{r}$60,366 |
| 1984 | $^{r}$24,660 | $^{r}$89,341 | $^{r}$6,143 | $^{r}$4,907 | 2,430 | 1,457 | $^{r}$6,426 | $^{r}$135,364 | $^{r}$34,424 | $^{r}$68,386 |
| 1985: | | | | | | | | | | |
| New England: | | | | | | | | | | |
| Connecticut | 392 | 1,187 | 543 | 79 | | | 272 | 2,550 | 53 | 160 |
| Maine, New Hampshire, Rhode Island, Vermont | 110 | 1,889 | 122 | 108 | 11 | 381 | 58 | 5,067 | 836 | 445 |
| Massachusetts | 339 | 1,940 | 14 | 172 | | | | | | |
| Total | 841 | 5,016 | 679 | 359 | 11 | 381 | 330 | 7,617 | 889 | 605 |
| Middle Atlantic: | | | | | | | | | | |
| New Jersey | 374 | 778 | 39 | 64 | | | 109 | 1,370 | 929 | 5,106 |
| New York | 470 | 6,160 | 207 | 500 | 185 | 205 | 59 | 7,461 | | |
| Pennsylvania | 4,424 | 5,982 | 399 | 418 | | | 1,097 | 12,639 | 3,866 | 5,061 |
| Total | 5,268 | 12,920 | 645 | 982 | 185 | 205 | 1,265 | 21,470 | 4,795 | 10,167 |
| East North Central: | | | | | | | | | | |
| Illinois | | 6,377 | 16 | 457 | | | 1,292 | 9,263 | 1,288 | 8,334 |
| Indiana | 2,512 | 11,083 | 329 | 150 | 1,221 | 519 | 28 | 13,153 | 482 | |
| Michigan | | 5,887 | 153 | 978 | | | 556 | 9,141 | 7,832 | 4,228 |
| Ohio | 5,347 | 7,419 | 116 | 343 | 2,181 | 112 | 335 | 14,773 | 6,591 | 7,458 |
| Wisconsin | | 7,890 | 1,957 | 396 | | | 74 | 11,398 | | 3,147 |
| Total | 7,859 | 38,656 | 2,571 | 2,324 | 3,402 | 631 | 2,285 | 57,728 | 16,193 | 23,167 |
| West North Central: | | | | | | | | | | |
| Iowa, Kansas, Minnesota | 148 | 4,020 | 76 | 307 | 61 | 5 | 173 | 4,776 | 2,044 | 2,737 |
| Missouri, Nebraska, South Dakota | 32 | 1,397 | 213 | 135 | | | 451 | 2,242 | | |
| Total | 180 | 5,417 | 289 | 442 | 61 | 5 | 624 | 7,018 | 2,044 | 2,737 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| South Atlantic: | | | | | | | | | | |
| Delaware, District of Columbia, Florida, Georgia, Maryland | 238 | 353 | 346 | 45 | 1 | 308 | 82 | 966 | 1,710 | 4,785 |
| North Carolina, South Carolina, Virginia, West Virginia | 86 | 8,784 | | 74 | | | 215 | 9,516 | | |
| Total | 324 | 9,137 | 346 | 119 | 1 | 308 | 247 | 10,482 | 1,710 | 4,785 |
| East South Central: | | | | | | | | | | |
| Alabama, Kentucky, Mississippi, Tennessee | 1,310 | 3,446 | 1 | 375 | | | | 5,495 | | 3,953 |
| West South Central: | | | | | | | | | | |
| Arkansas, Louisiana, Oklahoma, Texas | 2,659 | 6,004 | 155 | 78 | 149 | 121 | 1,051 | 9,839 | 9,242 | 270 |
| Mountain: | | | | | | | | | | |
| Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah | 262 | 493 | 119 | 6 | | | 18 | 913 | | 272 |
| Total | 4,231 | 9,943 | 275 | 459 | 149 | 121 | 1,069 | 16,247 | 9,242 | 4,495 |
| Pacific: | | | | | | | | | | |
| California | 1,279 | 6,797 | 903 | 524 | 59 | 22 | 929 | 9,490 | 795 | 7,076 |
| Oregon and Washington | 54 | 57 | | | | | | 1,134 | | 795 |
| Total | 1,333 | 6,854 | 903 | 524 | 59 | 22 | 929 | 10,624 | 795 | 7,871 |
| Grand total | 20,036 | 87,943 | 5,708 | 5,209 | 3,868 | 1,673 | 6,749 | 131,186 | 35,668 | 53,827 |

[r] Revised.

## Table 24.—Refined copper consumed in the United States, by class of consumer

(Metric tons)

| Class of consumer | Cathodes | Wirebars | Ingots and ingot bars | Cakes and slabs | Billets | Other | Total |
|---|---|---|---|---|---|---|---|
| 1984: | | | | | | | |
| Wire rod mills | [r]1,447,925 | 56,246 | W | W | -- | 523 | [r]1,504,694 |
| Brass mills | [r]261,622 | 13,268 | 58,480 | 127,448 | 115,191 | 151 | [r]576,160 |
| Chemical plants | W | -- | -- | -- | -- | [r]557 | [r]557 |
| Ingot makers | 2,657 | -- | 4,240 | -- | -- | (1) | [r]6,897 |
| Foundries | 762 | 2,548 | 8,456 | -- | 3,314 | 938 | 16,018 |
| Miscellaneous[2] | [r]8,917 | W | [r]3,218 | [r]195 | W | [r]6,076 | [r]18,406 |
| Total | [r]1,721,883 | 72,062 | [r]74,394 | [r]127,643 | 118,505 | [r]8,245 | [r]2,122,732 |
| 1985: | | | | | | | |
| Wire rod mills | 1,322,216 | 55,706 | W | W | -- | 664 | 1,378,586 |
| Brass mills | 197,228 | 13,723 | 43,346 | 114,360 | 116,628 | 58 | 485,343 |
| Chemical plants | W | -- | -- | -- | -- | 738 | 738 |
| Ingot makers | 1,054 | -- | 4,243 | -- | -- | 2 | 5,299 |
| Foundries | 969 | 904 | 9,048 | -- | 3,298 | 226 | 14,445 |
| Miscellaneous[2] | 10,920 | W | 3,217 | 1,412 | W | 5,674 | 21,223 |
| Total | 1,532,387 | 70,333 | 59,854 | 115,772 | 119,926 | 7,362 | 1,905,634 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Revised to zero.

[2] Includes iron and steel plants, primary smelters producing alloys other than copper, consumers of copper powder and copper shot, and other manufacturers.

## Table 25.—Stocks of copper in the United States, December 31

(Thousand metric tons)

| Period | Blister and materials in process of refining[1] | Refined copper | | | | | |
|---|---|---|---|---|---|---|---|
| | | Electrolytic refiners | Wire rod mills | Brass mills | Other[2] | New York Commodity Exchange | Total |
| 1981 | 277 | 151 | 109 | 26 | [r]29 | 170 | [r]485 |
| 1982 | 233 | 268 | 125 | 25 | [r]29 | 249 | [r]696 |
| 1983 | 174 | 154 | 116 | 26 | [r]25 | 371 | [r]692 |
| 1984 | [r]245 | [r]125 | [r]134 | 27 | [r]27 | 251 | [r]564 |
| 1985: | | | | | | | |
| January | 240 | 122 | 124 | 22 | 27 | 234 | 529 |
| February | 225 | 94 | 114 | 24 | 27 | 218 | 477 |
| March | 230 | 80 | 119 | 22 | 27 | 205 | 453 |
| April | 222 | 70 | 102 | 20 | 27 | 195 | 414 |
| May | 172 | 70 | 65 | 22 | 27 | 182 | 366 |
| June | 171 | 80 | 68 | 21 | 27 | 169 | 365 |
| July | 168 | 94 | 82 | 22 | 27 | 152 | 377 |
| August | 121 | 95 | 83 | 19 | 27 | 141 | 365 |
| September | 150 | 84 | 83 | 27 | 27 | 134 | 355 |
| October | 140 | 62 | 100 | 17 | 27 | 124 | 330 |
| November | 142 | 62 | 94 | 19 | 27 | 114 | 316 |
| December | 146 | 66 | 94 | 20 | 22 | 109 | 311 |

[r] Revised.

[1] Includes copper in transit from smelters in the United States to refineries therein.

[2] Includes secondary smelters, chemical plants, foundries, and miscellaneous plants; includes 20,000 tons in the National Defense Stockpile.

### Table 26.—Dealers' monthly average buying price for copper scrap and consumers' alloy-ingot prices at New York, by type

(Cents per pound)

| Year and month | Scrap | | Ingot | |
|---|---|---|---|---|
| | No. 2 heavy copper | No. 1 composition (red brass) | No. 115 brass (85-5-5-5) | Yellow brass (405) |
| 1984: | | | | |
| January | 41.17 | 42.83 | 84.00 | 69.75 |
| February | 40.60 | 42.60 | 85.25 | 71.93 |
| March | 43.59 | 45.05 | 87.36 | 74.61 |
| April | 44.50 | 45.50 | 88.50 | 75.75 |
| May | 43.30 | 45.50 | 87.23 | 74.48 |
| June | 42.21 | 44.60 | 86.50 | 73.75 |
| July | 39.36 | 42.50 | 86.50 | 73.75 |
| August | 38.50 | 42.50 | 86.50 | 73.75 |
| September | 38.08 | 42.08 | 86.50 | 73.75 |
| October | 36.20 | 41.07 | 86.50 | 73.75 |
| November | 34.50 | 40.50 | 84.50 | 71.75 |
| December | 35.67 | 40.50 | 81.58 | 69.81 |
| Average | 39.81 | 42.94 | 85.91 | 73.07 |
| 1985: | | | | |
| January | 37.50 | 40.50 | 81.50 | 70.75 |
| February | 37.50 | 40.50 | 81.50 | 70.75 |
| March | 37.50 | 40.50 | 81.50 | 70.75 |
| April | 37.50 | 40.50 | 81.50 | 70.75 |
| May | 37.50 | 39.50 | 81.50 | 70.75 |
| June | 37.50 | 39.50 | 81.50 | 70.75 |
| July | 37.50 | 39.50 | 81.50 | 70.75 |
| August | 37.50 | 39.50 | 81.50 | 70.75 |
| September | 37.50 | 39.50 | 81.50 | 70.75 |
| October | 37.50 | 39.50 | 81.50 | 70.75 |
| November | 37.50 | 39.50 | 81.50 | 70.75 |
| December | 37.50 | 39.50 | 81.50 | 70.75 |
| Average | 37.50 | 39.83 | 81.50 | 70.75 |

Source: American Metal Market.

## Table 27.—Average monthly prices for electrolytic copper in the United States and on the London Metal Exchange

(Cents per pound)

| Month | 1984 | | | | | 1985 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | U.S. producers delivered price | | COMEX first position | LME cash price[r 1] | | U.S. producers delivered price | | COMEX first position | LME cash price[1] | |
| | Cathode[2] | Wirebar[3] | | Cathode | High grade[4] | Cathode[2] | Wirebar[3] | | Cathode | High grade[4] |
| January | 66.10 | 68.79 | 62.30 | 61.65 | 62.38 | 64.49 | 64.49 | 59.15 | 61.19 | 61.63 |
| February | 68.35 | 70.75 | 64.22 | 64.09 | 64.84 | 66.45 | 66.45 | 60.57 | 62.79 | 62.96 |
| March | 72.71 | 75.31 | 67.91 | 67.79 | 68.07 | 65.55 | 65.55 | 60.09 | 62.91 | 63.02 |
| April | 74.67 | 77.39 | 68.46 | 69.36 | 69.50 | 70.32 | 70.32 | 63.62 | 67.11 | 68.08 |
| May | 69.55 | 72.23 | 63.40 | 64.49 | 64.43 | 69.86 | 69.86 | 62.95 | 67.67 | 69.38 |
| June | 67.29 | 69.85 | 61.04 | 62.10 | 61.91 | 67.09 | 67.09 | 60.15 | 64.31 | 64.95 |
| July | 64.40 | 64.40 | 58.60 | 60.64 | 60.35 | 66.77 | 66.77 | 60.78 | 64.73 | 66.86 |
| August | 64.54 | 64.54 | 59.35 | 61.14 | 60.65 | 66.35 | 66.35 | 60.19 | 62.40 | 64.39 |
| September | 63.41 | 63.41 | 57.06 | 58.94 | 58.66 | 65.72 | 65.72 | 59.57 | 60.74 | 61.96 |
| October | 62.04 | 62.04 | 56.34 | 57.87 | 57.73 | 66.68 | 66.68 | 60.97 | 61.57 | 62.79 |
| November | 65.65 | 65.65 | 59.63 | 61.43 | 60.99 | 66.29 | 66.29 | 60.64 | 60.70 | 62.10 |
| December | 63.54 | 63.54 | 57.54 | 60.30 | 59.91 | 68.03 | 68.03 | 63.18 | 62.13 | 63.07 |
| Average | 66.85 | 68.16 | 61.32 | 62.48 | 62.45 | 66.97 | 66.97 | 60.99 | 63.19 | 64.27 |

[r] Revised.

[1] Based on average monthly rates of exchange.

[2] Listed as "U.S. producer cathode."

[3] Listed as "U.S. producer delivered."

[4] Includes both cathode and wirebar.

Source: Metals Week.

## Table 28.—U.S. exports of copper, by country

| Country | Ore and concentrate (copper content) | | Ashes and residues[1] (copper content) | | Refined | | Scrap | | Blister and precipitates | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1984 | 60,999 | $69,085 | 5,150 | $11,911 | 91,414 | $138,834 | 80,810 | $96,266 | 8,379 | $10,562 |
| 1985: | | | | | | | | | | |
| Belgium-Luxembourg | 91 | 130 | 718 | 5,744 | 536 | 696 | 9,418 | 12,585 | -- | -- |
| Canada | 2,767 | 8,202 | 1,687 | 1,695 | 3,540 | 4,988 | 16,582 | 20,989 | 315 | 686 |
| China | -- | -- | 8,205 | 9,097 | -- | -- | -- | -- | -- | -- |
| France | -- | -- | -- | -- | 823 | 631 | 166 | 196 | -- | -- |
| Germany, Federal Republic of | -- | -- | 409 | 5,300 | 1,270 | 2,018 | 16,924 | 18,574 | 200 | 107 |
| Hong Kong | -- | -- | -- | -- | 971 | 1,514 | 1,442 | 776 | 71 | 62 |
| India | -- | -- | 744 | 677 | -- | -- | 999 | 859 | 40 | 29 |
| Italy | -- | -- | -- | -- | -- | -- | 6,854 | 6,625 | -- | -- |
| Japan | 102,833 | 108,932 | 97 | 381 | 5,002 | 7,708 | 13,451 | 15,803 | -- | -- |
| Korea, Republic of | 6,920 | 8,757 | -- | -- | 869 | 1,247 | 13,865 | 10,459 | 32,854 | 16,220 |
| Mexico | -- | -- | 73 | 186 | 4,229 | 2,956 | 12,254 | 13,774 | 5,610 | 3,220 |
| Netherlands | -- | -- | 11 | 13 | 17,824 | 25,207 | 3,986 | 4,081 | -- | -- |
| Spain | -- | -- | -- | -- | 2 | 4 | 4,802 | 4,715 | -- | -- |
| Sweden | -- | -- | 18 | 8 | 69 | 143 | 211 | 228 | -- | -- |
| Switzerland | -- | -- | -- | -- | 36 | 89 | 441 | 530 | 1 | 2 |
| Taiwan | 3,697 | 5,100 | -- | -- | 1,471 | 1,804 | 25,084 | 14,691 | 186 | 220 |
| United Kingdom | -- | -- | 102 | 86 | 671 | 1,351 | 3,904 | 4,988 | 99 | 93 |
| Yugoslavia | -- | -- | -- | -- | 1,512 | 1,899 | -- | -- | -- | -- |
| Other | (2) | 2 | 20 | 18 | 112 | 209 | 3,917 | 2,563 | 256 | 345 |
| Total | 116,308 | 131,123 | 12,084 | 23,200 | 37,987 | 52,464 | 134,300 | 132,386 | 39,632 | 20,984 |

See footnotes at end of table.

## Table 28.—U.S. exports of copper, by country—Continued

| Country | Pipes and tubing | | Plates and sheets | | Wire and cable, bare | | Wire and cable, insulated | | Other copper manufactures[3] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1984 | 4,304 | $13,541 | 4,647 | $10,387 | 7,379 | $22,023 | 28,141 | $167,214 | 13,817 | $30,438 |
| 1985: | | | | | | | | | | |
| Belgium-Luxembourg | -- | -- | 2 | 13 | (2) | 2 | 215 | 5,187 | 6 | 63 |
| Canada | 1,788 | 5,080 | 373 | 1,403 | 983 | 3,549 | 14,090 | 68,706 | 1,277 | 2,854 |
| China | (2) | 2 | -- | -- | -- | -- | 1,244 | 10,096 | 108 | 264 |
| Egypt | 15 | 56 | -- | -- | -- | -- | 1,285 | 5,863 | 469 | 938 |
| France | 3 | 79 | (2) | 1 | 7 | 268 | 741 | 26,012 | 2 | 24 |
| Germany, Federal Republic of | 8 | 32 | -- | -- | 30 | 285 | 1,827 | 27,677 | 10 | 129 |
| Haiti | 2 | 12 | -- | -- | 38 | 95 | 629 | 3,528 | 111 | 312 |
| Israel | 26 | 65 | 169 | 442 | 9 | 78 | 182 | 3,332 | 15 | 273 |
| Italy | 11 | 19 | 4 | 18 | 14 | 78 | 185 | 3,936 | 6 | 78 |
| Japan | -- | -- | 13 | 50 | 5 | 98 | 584 | 17,693 | 86 | 159 |
| Korea, Republic of | 1 | 34 | 3 | 126 | 12 | 81 | 1,380 | 8,308 | 262 | 404 |
| Mexico | 586 | 1,794 | 45 | 212 | 5,130 | 13,968 | 15,470 | 56,771 | 3,396 | 5,712 |
| Netherlands | 100 | 387 | (2) | 3 | 1 | 6 | 373 | 6,853 | 9 | 62 |
| Saudi Arabia | 594 | 1,924 | 24 | 200 | 127 | 472 | 2,529 | 11,707 | 110 | 466 |
| Spain | 166 | 423 | 22 | 87 | 10 | 33 | 85 | 7,358 | -- | -- |
| Sweden | -- | -- | -- | -- | -- | -- | 92 | 4,833 | 12 | 58 |
| Taiwan | 89 | 217 | 5 | 30 | 2 | 49 | 242 | 3,475 | 38 | 216 |
| United Kingdom | 181 | 497 | 27 | 80 | 43 | 396 | 2,390 | 33,332 | 33 | 199 |
| Other | 972 | 2,831 | 99 | 571 | 372 | 1,780 | 7,530 | 53,220 | 1,986 | 5,316 |
| Total | 4,542 | 13,452 | 786 | 3,236 | 6,783 | 21,188 | 51,073 | 357,887 | 7,883 | 17,522 |

[1] Includes matte.

[2] Less than 1/2 unit.

[3] Excludes copper wire cloth.

Source: Bureau of the Census.

## Table 29.—U.S. exports of copper scrap, by country

| Country | Unalloyed copper scrap | | | | Copper-alloy scrap | | | |
|---|---|---|---|---|---|---|---|---|
| | 1984 | | 1985 | | 1984 | | 1985 | |
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Belgium-Luxembourg | 2,005 | $5,174 | 9,418 | $12,535 | 3,112 | $7,027 | 6,314 | $6,875 |
| Canada | 11,249 | 14,630 | 16,582 | 20,989 | 30,895 | 37,715 | 23,968 | 35,329 |
| France | 52 | 76 | 166 | 196 | 205 | 523 | 205 | 230 |
| Germany, Federal Republic of | 2,968 | 2,488 | 16,924 | 18,574 | 3,732 | 3,496 | 17,067 | 18,435 |
| Hong Kong | 405 | 570 | 1,442 | 776 | 239 | 268 | 1,165 | 603 |
| India | -- | -- | 999 | 859 | 8,278 | 8,476 | 13,822 | 15,078 |
| Italy | 762 | 766 | 6,854 | 6,625 | 2,449 | 2,400 | 8,893 | 8,610 |
| Japan | 15,311 | 18,285 | 13,451 | 15,803 | 28,072 | 31,652 | 24,791 | 27,023 |
| Korea, Republic of | 13,278 | 15,678 | 13,865 | 10,459 | 7,614 | 8,735 | 12,422 | 13,498 |
| Mexico | 13,533 | 17,683 | 12,254 | 13,774 | 2,416 | 2,013 | 3,845 | 4,307 |
| Netherlands | 984 | 921 | 3,986 | 4,081 | 603 | 717 | 3,915 | 4,078 |
| Spain | 1,867 | 1,927 | 4,802 | 4,715 | 1,263 | 1,250 | 6,928 | 7,382 |
| Sweden | 441 | 559 | 211 | 228 | 2,556 | 3,414 | 1,808 | 2,520 |
| Switzerland | -- | -- | 441 | 530 | 471 | 307 | 646 | 633 |
| Taiwan | 15,813 | 14,090 | 25,084 | 14,691 | 14,642 | 13,959 | 14,724 | 10,635 |
| United Kingdom | 517 | 1,770 | 3,904 | 4,988 | 594 | 1,732 | 2,081 | 2,366 |
| Other | 1,625 | 1,649 | 3,917 | 2,563 | 1,190 | 1,263 | 3,265 | 2,277 |
| Total | 80,810 | 96,266 | 134,300 | 132,386 | 108,331 | 124,947 | 145,859 | 159,879 |

Source: Bureau of the Census.

Table 39.—U.S. imports for consumption of unmanufactured copper (copper content), by country

| Country | Ore and concentrate | | Matte | | Blister and anode | | Refined | | Unalloyed scrap | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1984 | 11,056 | $9,863 | 2,094 | $2,586 | 38,949 | $52,950 | 444,699 | $620,674 | 23,005 | $28,925 | 519,803 | $714,998 |
| 1985: | | | | | | | | | | | | |
| Australia | 1,112 | 641 | -- | -- | -- | -- | 8 | 36 | -- | -- | 1,120 | 677 |
| Belgium-Luxembourg | -- | -- | -- | -- | 10 | 28 | 5,321 | 7,060 | -- | -- | 5,331 | 7,088 |
| Canada | 396 | 404 | 2,170 | 1,397 | -- | -- | 127,990 | 172,823 | 18,278 | 20,664 | 148,834 | 195,288 |
| Chile | 16 | 22 | 178 | 1,663 | 8,119 | 9,465 | 155,686 | 198,484 | -- | -- | 163,999 | 209,634 |
| Costa Rica | -- | -- | -- | -- | -- | -- | -- | -- | 113 | 114 | 113 | 114 |
| Dominican Republic | -- | -- | -- | -- | -- | -- | -- | -- | 86 | 72 | 86 | 72 |
| France | -- | -- | -- | -- | -- | -- | 39 | 74 | 45 | 197 | 84 | 271 |
| Germany, Federal Republic of | -- | -- | -- | -- | 65 | 155 | 1,097 | 1,393 | 46 | 18 | 1,208 | 1,566 |
| Guatemala | -- | -- | -- | -- | -- | -- | -- | -- | 39 | 30 | 39 | 30 |
| Honduras | 75 | 89 | -- | -- | -- | -- | -- | -- | 44 | 34 | 119 | 123 |
| Jamaica | -- | -- | -- | -- | -- | -- | -- | -- | 145 | 122 | 145 | 122 |
| Japan | 476 | 115 | -- | -- | 982 | 1,415 | 509 | 1,110 | -- | -- | 1,967 | 2,640 |
| Korea, Republic of | -- | -- | -- | -- | -- | -- | 2,160 | 2,924 | 260 | 329 | 2,420 | 3,253 |
| Mexico | -- | -- | 15 | 27 | 2,041 | 2,187 | 2,289 | 3,320 | 3,149 | 3,346 | 7,494 | 8,880 |
| Netherlands | -- | -- | 823 | 901 | -- | -- | -- | -- | -- | -- | 823 | 901 |
| Norway | -- | -- | -- | -- | -- | -- | 940 | 1,309 | -- | -- | 940 | 1,309 |
| Panama | -- | -- | -- | -- | -- | -- | -- | -- | 389 | 400 | 389 | 400 |
| Peru | 794 | 468 | 110 | 2,580 | 1,549 | 1,994 | 32,562 | 40,685 | -- | -- | 35,015 | 45,727 |
| South Africa, Republic of | -- | -- | 99 | 54 | -- | -- | 5,854 | 7,698 | -- | -- | 5,953 | 7,752 |
| Switzerland | -- | -- | -- | -- | -- | -- | -- | -- | 13 | 15 | 13 | 15 |
| Taiwan | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 3 | 1 | 3 |
| Trinidad | -- | -- | -- | -- | -- | -- | -- | -- | 88 | 43 | 88 | 43 |
| United Kingdom | -- | -- | -- | -- | -- | -- | 3,213 | 4,664 | 63 | 16 | 3,276 | 4,680 |
| Venezuela | -- | -- | 602 | 375 | -- | -- | -- | -- | 149 | 160 | 751 | 535 |
| Zaire | -- | -- | -- | -- | -- | -- | 28,502 | 34,694 | -- | -- | 28,502 | 34,694 |
| Zambia | -- | -- | -- | -- | 139 | 180 | 11,429 | 15,323 | -- | -- | 11,568 | 15,503 |
| Other | -- | -- | -- | -- | 74 | 105 | 126 | 201 | 106 | 117 | 306 | 423 |
| Total | 2,869 | 1,739 | 3,997 | 6,997 | 12,979 | 15,529 | 377,725 | 491,798 | 23,014 | 25,680 | 420,584 | 541,743 |

Source: Bureau of the Census.

## Table 31.—U.S. imports for consumption of copper scrap, by country

| Country | Unalloyed copper scrap: Quantity (metric tons) | Unalloyed copper scrap: Value (thousands) | Copper-alloy scrap: Gross weight (metric tons) | Copper-alloy scrap: Copper content (metric tons) | Copper-alloy scrap: Value (thousands) |
|---|---|---|---|---|---|
| 1978 | [r]15,436 | [r]$16,583 | 19,018 | 13,199 | $18,044 |
| 1979 | [r]14,652 | [r]21,483 | 21,624 | 14,983 | 25,796 |
| 1980 | [r]16,053 | [r]28,540 | 19,162 | 13,704 | 26,806 |
| 1981 | [r]17,640 | [r]25,328 | 24,101 | 17,539 | 30,562 |
| 1982 | [r]16,459 | [r]20,550 | 25,449 | 18,844 | 24,247 |
| 1983 | 23,086 | 32,183 | 42,006 | 31,832 | 48,597 |
| 1984 | 23,005 | 28,925 | 42,357 | 31,999 | 47,333 |
| 1985: | | | | | |
| Canada | 18,278 | 20,664 | 20,557 | 15,624 | 21,287 |
| Chile | -- | -- | 90 | 51 | 143 |
| Costa Rica | 113 | 114 | 76 | 59 | 72 |
| Dominican Republic | 86 | 72 | 418 | 369 | 398 |
| France | 45 | 197 | 54 | 47 | 66 |
| Germany, Federal Republic of | 46 | 18 | 121 | 88 | 165 |
| Guatemala | 39 | 30 | 45 | 39 | 21 |
| Honduras | 44 | 34 | 26 | 22 | 19 |
| Jamaica | 145 | 122 | 127 | 110 | 78 |
| Japan | -- | -- | 38 | 27 | 101 |
| Korea, Republic of | 260 | 329 | 7 | 7 | 16 |
| Mexico | 3,149 | 3,346 | 8,873 | 5,757 | 9,134 |
| Panama | 389 | 400 | 469 | 354 | 387 |
| Philippines | -- | -- | 125 | 109 | 126 |
| Switzerland | 13 | 15 | 31 | 29 | 70 |
| Taiwan | 1 | 3 | 150 | 117 | 231 |
| Trinidad | 88 | 43 | 40 | 25 | 17 |
| United Kingdom | 63 | 16 | 278 | 200 | 429 |
| Venezuela | 149 | 160 | 233 | 186 | 241 |
| Other | 106 | 117 | 176 | 128 | 202 |
| **Total** | **23,014** | **25,680** | **31,934** | **23,348** | **33,203** |

[r] Revised.

Source: Bureau of the Census.

## Table 32.—Copper: World mine production,[1] by country

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Albania[e] | [r]12.0 | [r]13.2 | [r]14.3 | [r]16.1 | 16.2 |
| Algeria | .2 | .1 | .1 | .1 | .1 |
| Argentina | .1 | ([2]) | .3 | .3 | .3 |
| Australia | 231.3 | 245.3 | 261.5 | 236.0 | 258.0 |
| Bolivia | 2.6 | 2.3 | 2.0 | 1.6 | 1.5 |
| Botswana[3] | 17.8 | 18.4 | 20.3 | 21.5 | 22.0 |
| Brazil | 11.8 | 24.4 | 40.0 | 44.4 | 32.0 |
| Bulgaria | 62.0 | 70.0 | 80.0 | [e]80.0 | 80.0 |
| Burma | ([2 3]) | ([2 3]) | 4.2 | [e]12.0 | [4]16.7 |
| Canada[5] | 691.3 | 612.4 | 653.0 | 712.8 | 724.4 |
| Chile[6] | 1,081.1 | 1,242.2 | 1,257.5 | 1,290.7 | [4]1,356.4 |
| China[e] | 170.0 | 175.0 | 175.0 | 180.0 | 185.0 |
| Colombia | [r].5 | [r].5 | .4 | .8 | .8 |
| Congo (Brazzaville) | .2 | .1 | .1 | ([2]) | ([2]) |
| Cuba | 2.9 | 2.6 | 2.7 | 2.7 | 3.1 |
| Cyprus[7] | -- | .8 | 1.2 | ([2]) | ([2]) |
| Czechoslovakia | [r]9.2 | [r]9.3 | 9.8 | 10.0 | 10.3 |
| Ecuador | .8 | [r]([2]) | ([2]) | [e].2 | .1 |
| Finland | [r]38.5 | 37.8 | 39.3 | 31.3 | 30.0 |
| France | .1 | .2 | .1 | .1 | .1 |
| German Democratic Republic[e] | 12.0 | 13.0 | 12.0 | 12.0 | 10.0 |
| Germany, Federal Republic of[5] | 1.4 | 1.3 | 1.2 | [e]1.0 | [4].9 |
| Greece | .1 | -- | -- | -- | -- |
| Guatemala | .7 | [e].7 | ([8]) | ([8]) | -- |
| Honduras | .5 | .5 | .6 | [e].7 | .8 |
| India | 25.2 | [e]24.0 | 37.8 | 44.1 | [4]42.8 |
| Indonesia | 62.5 | [r]75.1 | 78.6 | 82.5 | [4]88.7 |
| Iran[e] | 2.0 | 43.0 | 65.0 | 60.0 | 60.0 |
| Ireland | 3.5 | 1.6 | -- | -- | -- |
| Israel | NA | [r]3.5 | 3.5 | [r] [e]2.9 | -- |

See footnotes at end of table.

## Table 32.—Copper: World mine production,[1] by country —Continued

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Italy | .8 | [r].1 | 1.5 | .9 | .1 |
| Japan | 51.5 | 50.7 | 46.0 | 43.3 | [4]43.2 |
| Korea, North[e] | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| Korea, Republic of | .5 | [e].3 | .4 | .3 | .3 |
| Malaysia | 28.6 | [r]30.1 | 29.0 | 28.9 | [4]30.5 |
| Mexico | 232.9 | 229.2 | 196.0 | 303.5 | 290.0 |
| Mongolia[e] | 71.8 | 90.0 | 104.0 | 118.0 | 123.0 |
| Morocco | [r]8.3 | [r]22.7 | 23.8 | 22.1 | 22.0 |
| Mozambique[e] | .2 | [r].3 | .2 | [r].3 | .3 |
| Namibia | 46.1 | 49.8 | 50.4 | 47.4 | [4]48.0 |
| Nepal | (2) | (2) | (2) | (2) | (2) |
| Norway | [r]28.1 | [r]27.6 | 22.6 | 22.3 | [4]19.0 |
| Oman | -- | -- | 11.8 | 16.2 | 18.0 |
| Papua New Guinea | 165.4 | 170.0 | 201.9 | 164.5 | [4]175.0 |
| Peru[6] | 342.1 | 356.6 | 322.2 | 375.1 | [4]397.2 |
| Philippines | 302.3 | 292.1 | 271.4 | 233.4 | [4]226.2 |
| Poland | [r]294.6 | [r]376.0 | 402.3 | 431.0 | 431.3 |
| Portugal[e] [10] | [r].6 | [r].4 | .4 | .4 | [4].3 |
| Romania[e] [5] | 27.0 | 26.0 | 27.0 | 25.0 | 26.0 |
| South Africa, Republic of[6] | [r]199.4 | 188.7 | 205.0 | 198.2 | [4]202.3 |
| Spain | 50.9 | 47.6 | 50.0 | 63.1 | [4]56.4 |
| Sweden | [r]50.7 | [r]55.4 | 74.6 | 85.8 | [4]91.8 |
| Taiwan[e] | .5 | -- | -- | (2) | -- |
| Turkey[11] | 31.9 | 34.4 | 25.0 | 32.1 | 32.5 |
| U.S.S.R.[e] [5] | 570.0 | 560.0 | 570.0 | 590.0 | 600.0 |
| United Kingdom | [r].6 | .6 | .7 | .7 | .7 |
| United States:[5] | | | | | |
| By concentration or leaching | [r]1,406.8 | [r]1,023.2 | 933.1 | 996.0 | [4]1,007.3 |
| Leaching (electrowon) | [r]131.4 | [r]123.8 | 105.0 | 106.6 | [4]96.5 |
| Yugoslavia[11] | [r]111.0 | 119.3 | 129.8 | 137.6 | 150.0 |
| Zaire | 555.1 | 519.0 | 536.5 | 520.0 | 560.0 |
| Zambia:[12] | | | | | |
| By concentration or leaching | 465.8 | 436.9 | 455.6 | 406.6 | 363.0 |
| Leaching (electrowon) | 122.2 | 130.9 | 118.9 | 134.4 | 120.0 |
| Zimbabwe | 24.6 | 24.7 | 21.6 | 23.6 | 21.0 |
| Total | [r]7,777.0 | [r]7,618.7 | 7,711.7 | 7,936.1 | 8,114.1 |

[e] Estimated. [p] Preliminary. [r] Revised. NA Not available.

[1] Data represent copper content by analysis of concentrates produced except where otherwise specified. Table includes data available through July 8, 1986.

[2] Less than 50 tons.

[3] Copper content of matte produced.

[4] Reported figure.

[5] Recoverable content.

[6] Copper content by analysis of concentrates for export plus nonduplicative total of copper content of all metal and metal products produced indigenously from domestic ores and concentrates. Includes leach production for electrowinning.

[7] Includes copper content of cupriferous pyrite.

[8] Revised to zero.

[9] Data are for years beginning Mar. 21 of that stated.

[10] Calculated from gross weight of ore using 21.6% copper content.

[11] Copper content by analysis of ore mined.

[12] Data are for fiscal years ending Mar. 31 of year stated.

## Table 33.—Copper: World smelter production,[1] by country

(Thousand metric tons)

| Country[2] and metal origin | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Albania, primary | [r]9.1 | [r]10.2 | 11.0 | 12.6 | 12.6 |
| Australia: | | | | | |
| Primary | 172.2 | 175.5 | 173.6 | 179.8 | 167.0 |
| Secondary | 5.0 | 4.8 | [e]5.0 | [e]5.0 | 4.7 |
| Total | 177.2 | 180.3 | [e]178.6 | [r] [e]184.8 | 171.7 |
| Austria, secondary | 27.1 | 30.0 | 30.0 | 30.0 | 36.0 |
| Belgium:[e] | | | | | |
| Primary | 3.1 | 2.5 | 2.8 | [r].5 | .5 |
| Secondary | 47.5 | 47.5 | 47.5 | [r]10.0 | 10.0 |
| Total | 50.6 | 50.0 | 50.3 | [r]10.5 | 10.5 |
| Brazil, primary | -- | [r]4.8 | 63.1 | 61.3 | 60.0 |
| Bulgaria:[e] | | | | | |
| Primary | [r]59.0 | [r]59.0 | [r]57.0 | [r]57.0 | 87.0 |
| Secondary | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Total | [r]62.0 | [r]62.0 | [r]60.0 | [r]60.0 | 90.0 |
| Canada: | | | | | |
| Primary | 450.1 | 394.3 | 499.7 | 504.3 | 488.0 |
| Secondary[e] | 15.0 | 10.0 | 11.0 | 11.0 | 17.0 |
| Total[e] | 465.1 | 404.3 | 510.7 | [r]515.3 | 505.0 |
| Chile, primary[3] | 953.8 | 1,046.8 | 1,058.9 | 1,098.3 | [4]1,068.5 |
| China, primary[e] | 190.0 | 205.0 | 195.0 | 210.0 | 225.0 |
| Czechoslovakia: | | | | | |
| Primary | 8.0 | 10.8 | 10.0 | 10.0 | [4]10.2 |
| Secondary | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |
| Total[e] | [r]10.4 | [r]13.2 | [r]12.4 | [r]12.4 | 12.6 |
| Finland: | | | | | |
| Primary | 54.7 | 66.3 | 74.5 | 71.2 | 71.0 |
| Secondary | 13.0 | 19.1 | 12.6 | 12.1 | 12.0 |
| Total | 67.7 | 85.4 | 87.1 | 83.3 | 83.0 |
| France, secondary | 6.5 | [r]8.1 | 7.2 | 6.8 | 7.0 |
| German Democratic Republic, primary[e] | 16.0 | 17.0 | 17.0 | [r]14.0 | 11.0 |
| Germany, Federal Republic of: | | | | | |
| Primary | 163.1 | 161.8 | 159.1 | 148.8 | 160.0 |
| Secondary | 88.3 | 78.2 | 94.5 | 76.7 | 80.0 |
| Total | 251.4 | 240.0 | 253.6 | 225.5 | 240.0 |
| Hungary, secondary[e] | .1 | .1 | .1 | .1 | .1 |
| India, primary | 25.7 | 32.6 | 35.5 | 40.5 | 34.0 |
| Iran, primary[3] | .8 | [r]18.0 | [r]18.0 | [r]50.0 | 40.0 |
| Japan: | | | | | |
| Primary | 930.0 | 948.2 | 944.6 | 821.1 | [4]802.3 |
| Secondary | 50.1 | 98.1 | 117.3 | 107.9 | [4]130.3 |
| Total | 980.1 | 1,046.3 | 1,061.9 | 929.0 | [4]932.6 |
| Korea, North:[e] | | | | | |
| Primary | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| Secondary | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Total | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 |
| Korea, Republic of, primary and secondary | 101.2 | 119.4 | 124.0 | 100.2 | 106.9 |
| Mexico, primary | [r]69.2 | [r]77.5 | 92.0 | 80.3 | 80.0 |
| Namibia, primary | 39.7 | 49.8 | 54.2 | 46.4 | [4]43.3 |
| Norway, primary (including electrowon) | 32.0 | 24.4 | 27.2 | 37.0 | 38.2 |
| Oman, primary | -- | -- | 7.6 | 21.3 | 15.0 |
| Peru, primary | 279.3 | 294.4 | 258.3 | 298.8 | 326.6 |
| Philippines, primary | -- | -- | 57.6 | 109.2 | [4]125.0 |
| Poland:[e] | | | | | |
| Primary | 315.0 | 338.0 | 349.0 | 360.0 | 370.0 |
| Secondary | 15.8 | 13.0 | 13.0 | 15.0 | 20.0 |
| Total | [4]330.8 | 351.0 | 362.0 | 375.0 | 390.0 |

See footnotes at end of table.

## Table 33.—Copper: World smelter production,[1] by country —Continued

(Thousand metric tons)

| Country[2] and metal origin | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Portugal: | | | | | |
| Primary[e] | [r]2.8 | 1.1 | [r]3.2 | [r]2.5 | 3.0 |
| Secondary[e] | .4 | .4 | 3.0 | [r]1.0 | 2.0 |
| Total | [r]3.2 | 1.5 | 6.2 | 3.5 | 5.0 |
| Romania:[e] | | | | | |
| Primary | [4]39.4 | 35.0 | 34.0 | 32.0 | 32.0 |
| Secondary | 4.0 | 4.0 | [r]6.0 | 6.0 | 6.0 |
| Total | 43.4 | 39.0 | [r]40.0 | 38.0 | 38.0 |
| South Africa, Republic of, primary | 185.4 | [r]191.8 | 192.3 | 178.7 | [4]159.7 |
| Spain: | | | | | |
| Primary | 87.9 | 105.0 | 100.0 | 97.0 | 100.0 |
| Secondary | 20.0 | 30.0 | 18.0 | 30.0 | 25.0 |
| Total | 107.9 | 135.0 | 118.0 | 127.0 | 125.0 |
| Sweden: | | | | | |
| Primary | 60.6 | 72.5 | 78.7 | 79.8 | [4]56.1 |
| Secondary | 13.2 | 17.4 | 23.1 | 22.9 | [4]18.4 |
| Total | 73.8 | 89.9 | 101.8 | 102.7 | [4]74.5 |
| Taiwan, primary | 53.1 | 47.3 | 37.9 | 48.4 | 47.0 |
| Turkey: | | | | | |
| Primary | [r]27.0 | [r]25.5 | 18.8 | 31.8 | 31.8 |
| Secondary | [r].3 | [r].2 | .3 | .2 | .2 |
| Total | 27.3 | [r]25.7 | 19.1 | 32.0 | 32.0 |
| U.S.S.R.:[e] | | | | | |
| Primary | 673.0 | 680.0 | 700.0 | 734.0 | 750.0 |
| Secondary | 137.0 | 138.0 | 139.0 | 141.0 | 143.0 |
| Total | 810.0 | 818.0 | 839.0 | 875.0 | 893.0 |
| United States: | | | | | |
| Primary[5] | 1,316.8 | 975.7 | 927.7 | 1,014.1 | [4]943.5 |
| Secondary | 60.9 | 45.1 | 59.3 | 169.3 | [4]249.9 |
| Total[6] | 1,377.6 | 1,020.8 | 987.0 | 1,183.4 | [4]1,193.4 |
| Yugoslavia, primary | 92.5 | 94.0 | 86.8 | [r] [e]90.0 | 100.0 |
| Zaire, primary: | | | | | |
| Electrowon | 301.9 | 302.4 | 304.1 | 309.1 | 310.0 |
| Other | 178.5 | 171.1 | 175.0 | 171.5 | 170.0 |
| Total | 480.4 | 473.5 | 479.1 | 480.6 | 480.0 |
| Zambia, primary | 560.6 | 584.7 | 562.7 | 531.8 | 508.2 |
| Zimbabwe, primary | [e]23.0 | [e]23.2 | 21.6 | 22.7 | 28.0 |
| Grand total | [r]8,002.1 | [r]7,933.0 | 8,142.8 | 8,344.4 | 8,386.4 |
| Of which: | | | | | |
| Primary: | | | | | |
| Electrowon | 301.9 | 302.4 | 304.1 | 309.1 | 310.0 |
| Other | [r]7,086.4 | [r]6,958.8 | 7,119.4 | 7,281.7 | 7,199.5 |
| Secondary | [r]512.6 | [r]552.4 | 595.3 | 653.4 | 770.0 |
| Undifferentiated | 101.2 | 119.4 | 124.0 | 100.2 | 106.9 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] This table includes total production of copper metal at the unrefined stage, including low-grade cathode produced by electrowinning methods. The smelter feed may be derived from ore, concentrates, copper precipitate or matte (primary), and/or scrap (secondary). To the extent possible, primary and secondary output of each country is shown separately. In some cases, total smelter production is officially reported, but the distribution between primary and secondary has been estimated. Table includes data available through July 8, 1986.

[2] Argentina presumably produces some smelter copper utilizing its own small mine output together with domestically produced cement copper, and possibly using other raw materials including scrap, but the levels of such output cannot be reliably estimated.

[3] Data include electrowon production; estimated to be 35,000 to 45,000 tons per year that is fire-refined and cast into wirebars; detailed data are not available.

[4] Reported figure.

[5] Figures for U.S. primary smelter production may include a small amount of copper derived from precipitates shipped directly to the smelter for further processing; production derived from electrowinning and fire-refining is not included. Copper content of precipitates shipped directly to smelter are as follows, in metric tons: 1981—113,991; 1982—104,791; 1983—89,274; 1984—80,845; and 1985—82,948. Production from scrap prior to 1984 excludes data from secondary smelters processing only scrap.

[6] Data may not add to totals shown because of independent rounding.

## Table 34.—Copper: World refinery production,[1] by country

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Albania, primary[e] | 9.0 | [r]9.5 | [r]10.5 | [r]11.5 | 11.5 |
| Australia: | | | | | |
| Primary | 164.2 | 160.2 | 168.5 | 171.7 | [2]163.7 |
| Secondary | [r]26.8 | 17.9 | 34.1 | [e]35.0 | 35.0 |
| Total | [r]191.0 | 178.1 | 202.6 | [e]206.7 | 198.7 |
| Austria: | | | | | |
| Primary | 8.8 | 8.8 | 8.8 | 9.6 | 9.0 |
| Secondary | 30.3 | 32.8 | 33.1 | 34.2 | 34.0 |
| Total | 39.1 | 41.6 | 41.9 | 43.8 | 43.0 |
| Belgium: | | | | | |
| Primary | [r]378.6 | [r]420.6 | 360.3 | 351.7 | 320.0 |
| Secondary | 58.0 | 81.0 | 71.0 | 76.0 | 80.0 |
| Total | [r]436.6 | [r]501.6 | 431.3 | 427.7 | 400.0 |
| Brazil: | | | | | |
| Primary | -- | [r]4.8 | 63.1 | 61.3 | 70.0 |
| Secondary | 45.0 | [r]52.0 | 39.3 | 36.0 | 40.0 |
| Total | 45.0 | [r]56.8 | 102.4 | 97.3 | 110.0 |
| Bulgaria, primary and secondary[e] | 62.0 | 65.0 | 62.0 | 62.0 | 93.0 |
| Canada: | | | | | |
| Primary | 476.7 | 337.8 | 464.3 | 504.3 | 488.0 |
| Secondary[e] | 31.9 | 16.5 | 33.0 | 35.0 | 34.0 |
| Total[e] | 508.6 | 354.3 | 497.3 | [r]539.3 | 522.0 |
| Chile, primary | 775.6 | 852.5 | 834.2 | 879.7 | [2]884.3 |
| China, primary and secondary[e] | 295.0 | 300.0 | 310.0 | 310.0 | 400.0 |
| Czechoslovakia, primary and secondary | 25.5 | 25.6 | 25.7 | 26.1 | 26.5 |
| Egypt, secondary | 2.0 | 2.4 | 2.4 | [e]2.6 | 1.6 |
| Finland: | | | | | |
| Primary | 23.8 | 38.0 | 45.4 | 47.3 | 46.5 |
| Secondary[e] | 10.0 | 10.0 | 10.0 | 10.0 | 12.0 |
| Total | 33.8 | 48.0 | 55.4 | 57.3 | 58.5 |
| France: | | | | | |
| Primary[e] | 23.0 | 24.0 | [r]23.0 | [r]30.0 | 23.5 |
| Secondary[e] | 23.0 | 23.1 | [r]22.1 | [r]20.0 | 21.0 |
| Total[3] | 46.0 | 47.1 | 45.1 | 49.9 | 44.5 |
| German Democratic Republic, primary and secondary[e] | 54.0 | 51.0 | 50.0 | [r]55.5 | 55.0 |
| Germany, Federal Republic of: | | | | | |
| Primary | 304.1 | 313.7 | 332.8 | 297.9 | [2]330.0 |
| Secondary | 83.4 | 80.4 | 87.9 | 81.1 | [2]84.3 |
| Total[3] | 387.4 | 394.1 | 420.8 | 379.0 | [2]414.3 |
| Hungary, primary and secondary[e] | 12.0 | [2]12.2 | 12.5 | 12.8 | 12.8 |
| India: | | | | | |
| Primary: | | | | | |
| Electrolytic | 24.0 | 25.6 | 28.4 | 32.6 | 27.0 |
| Fire refined | 1.2 | 1.2 | 1.0 | 1.0 | 1.0 |
| Secondary | ([4]) | ([4]) | ([4]) | ([4]) | -- |
| Total | 25.2 | [r]26.8 | 29.4 | 33.6 | 28.0 |
| Iran, primary[5] | .8 | 1.0 | 10.0 | [r] [e]10.0 | 12.0 |
| Italy: | | | | | |
| Primary[e] | 1.0 | -- | -- | -- | -- |
| Secondary[e] | 22.7 | 19.6 | [r]31.2 | [r]40.0 | 35.0 |
| Total | 23.7 | 19.6 | 31.2 | 40.0 | 35.0 |
| Japan: | | | | | |
| Primary | 930.0 | 948.2 | 944.6 | 821.1 | [2]802.3 |
| Secondary | 120.2 | 126.8 | 147.4 | 114.1 | [2]133.6 |
| Total[3] | 1,050.1 | 1,075.0 | 1,091.9 | 935.2 | [2]936.0 |

See footnotes at end of table.

## Table 34.—Copper: World refinery production,[1] by country —Continued

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Korea, North, primary and secondary[e] | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 |
| Korea, Republic of: | | | | | |
| Primary | 108.0 | 110.8 | 123.3 | 129.1 | 140.0 |
| Secondary[e] | 5.0 | 5.0 | 11.5 | 7.9 | 10.0 |
| Total[e] | 113.0 | 115.8 | 134.8 | 137.0 | 150.0 |
| Mexico: | | | | | |
| Primary | 61.3 | 61.4 | 80.9 | 69.8 | 76.8 |
| Secondary[e] | 10.0 | 14.0 | 15.0 | [3]13.8 | 14.0 |
| Total[e] | 71.3 | 75.4 | 95.9 | [3]83.6 | 90.8 |
| Norway: | | | | | |
| Primary (electrowon)[6] | 26.1 | 18.0 | 22.7 | 30.3 | [3]31.1 |
| Secondary[e] | 6.0 | 6.0 | [3]2.0 | [r]2.0 | 2.0 |
| Total[e] | 32.1 | 24.0 | [3]24.7 | [r]32.3 | 33.1 |
| Oman, primary | -- | -- | 3.8 | 15.1 | 16.0 |
| Peru, primary: | | | | | |
| Electrowon | 33.8 | 33.9 | 33.0 | 30.8 | [3]27.4 |
| Other | 175.6 | 194.4 | 158.1 | 188.6 | [3]200.6 |
| Total | 209.4 | 228.3 | 191.1 | 219.4 | [3]228.0 |
| Philippines, primary | -- | -- | 38.8 | 99.2 | [3]130.3 |
| Poland, primary[7] | 327.2 | 348.0 | 360.0 | 372.3 | [3]387.0 |
| Portugal, primary | 4.8 | 4.6 | [e]4.6 | [e]4.6 | 4.5 |
| Romania:[e] | | | | | |
| Primary | 39.4 | 38.0 | 35.0 | 33.0 | 33.0 |
| Secondary | 20.6 | 12.0 | 12.0 | 12.0 | 12.0 |
| Total | 60.0 | 50.0 | 47.0 | 45.0 | 45.0 |
| South Africa, Republic of, primary[8] | 144.1 | 142.8 | 157.7 | 155.7 | [3]161.5 |
| Spain: | | | | | |
| Primary | 137.1 | [e]151.3 | 141.5 | 118.1 | 125.0 |
| Secondary | 15.0 | [e]20.6 | 17.1 | 38.3 | 30.0 |
| Total | 152.1 | 171.9 | 158.6 | 156.4 | 155.0 |
| Sweden: | | | | | |
| Primary | [r]58.7 | 58.1 | 59.0 | [r] [e]59.4 | 60.2 |
| Secondary | [r]3.2 | 4.2 | 4.3 | [r] [e]4.5 | 4.5 |
| Total[3] | 61.9 | 62.3 | 63.4 | 63.9 | [3]64.7 |
| Taiwan: | | | | | |
| Primary[e] | 45.2 | 39.4 | 30.0 | 40.4 | 39.0 |
| Secondary[e] | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| Total | 53.2 | 47.4 | 38.0 | 48.4 | 47.0 |
| Turkey, primary | [r]22.4 | 32.2 | 31.8 | 39.0 | 30.0 |
| U.S.S.R.:[e] | | | | | |
| Primary | 730.0 | 759.0 | 776.0 | 798.0 | 810.0 |
| Secondary | 137.0 | 138.0 | 139.0 | 141.0 | 143.0 |
| Total | 867.0 | 897.0 | 915.0 | 939.0 | 953.0 |
| United Kingdom: | | | | | |
| Primary | 59.8 | 63.2 | 67.5 | 69.5 | 64.0 |
| Secondary | 76.3 | 71.0 | 76.8 | 67.4 | 62.0 |
| Total[3] | 136.2 | [r]134.1 | 144.4 | 136.8 | 126.0 |
| United States: | | | | | |
| Primary: | | | | | |
| Electrowon | 161.1 | 131.9 | 126.7 | 127.3 | 109.6 |
| Other | 1,382.9 | 1,094.9 | 1,055.4 | 1,037.3 | 947.6 |
| Secondary | [r]482.8 | 467.5 | 401.7 | 324.9 | 379.2 |
| Total[3] | [r]2,026.9 | 1,694.3 | 1,583.8 | 1,489.5 | 1,436.3 |

See footnotes at end of table.

## Table 34.—Copper: World refinery production,[1] by country —Continued

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Yugoslavia: | | | | | |
| Primary | 90.7 | 82.5 | 82.9 | [r] [e]94.0 | 100.0 |
| Secondary | 41.9 | 44.4 | 40.8 | 33.6 | 35.4 |
| Total | 132.6 | 126.9 | 123.7 | 127.6 | [2]135.4 |
| Zaire, primary | 151.3 | 175.0 | 227.2 | 224.8 | [2]226.8 |
| Zambia, primary: | | | | | |
| Electrowon | 122.2 | 130.9 | 119.0 | 134.4 | 120.0 |
| Other | 438.2 | 453.7 | 456.4 | 387.5 | 360.0 |
| Total | 560.4 | 584.6 | 575.4 | 521.9 | 480.0 |
| Zimbabwe, primary | 8.0 | 23.0 | 21.6 | [r] [e]22.7 | 20.4 |
| Grand total[3] | [r]9,178.3 | [r]9,021.8 | 9,229.9 | 9,136.2 | 9,229.5 |
| Of which: | | | | | |
| Primary | [r]7,448.7 | [r]7,292.9 | 7,507.8 | 7,510.6 | 7,409.6 |
| Secondary | [r]1,259.1 | [r]1,253.2 | 1,239.7 | 1,137.4 | 1,210.6 |
| Primary and secondary, undifferentiated | 470.5 | 475.8 | 482.2 | 488.4 | 609.3 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] This table includes total production of refined copper, whether produced by pyrometallurgical or electrolytic refining methods, and whether derived from primary unrefined copper or from scrap. Copper cathode derived from electrowinning processing is also included. To the extent possible, primary and secondary output of each country is shown separately. In most cases, total refinery production is officially reported, and in some, the distribution between primary and secondary has been estimated. Table includes data available through July 8, 1986.

[2] Reported figure.

[3] Data may not add to totals shown because of independent rounding.

[4] Revised to zero.

[5] Data are for years beginning Mar. 21 of that stated.

[6] Includes electrowon cathode produced from imported matte.

[7] May include small quantities of secondary.

[8] Although only primary production is reported, an unknown but small additional output of secondary refined copper may have been produced.

# Diatomite

## By A. C. Meisinger[1]

The quantity of processed diatomite produced in 1985 was 635,000 short tons, a slight increase over that of 1984. Of the four Western States with reported production, California continued to be the leading producing State.

Diatomite exports declined 6% to 120,000 tons and comprised 19% of domestic production. World production was estimated to be nearly 2 million tons.

**Domestic Data Coverage.**—Domestic production data for diatomite are developed by the Bureau of Mines from one voluntary survey of U.S. plant operations. Of the nine operations to which a survey request was sent, 100% responded, representing 100% of the total production shown in tables 1 and 5.

**Table 1.—Diatomite sold or used by producers in the United States**

(Thousand short tons and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Domestic production (sales) | 687 | 618 | 619 | 627 | 635 |
| Total value of sales | $118,010 | $107,619 | $114,279 | $120,926 | $127,090 |

## DOMESTIC PRODUCTION

Output of diatomite by domestic producers was 635,000 tons valued at $127 million, a slight increase over 1984 output. Diatomite was processed by seven companies in nine plants in four States. California continued to be the leading producing State, followed by Nevada, Washington, and Oregon.

The major diatomite producers continued to be Manville Products Corp., with operations at Lompoc, CA; Grefco Inc., Dicalite Div., at Lompoc, CA, and Mina, NV; Eagle-Picher Industries Inc. at Sparks and Lovelock, NV; and Witco Corp. (formerly Witco Chemical Corp.), Inorganic Specialties Div., at Quincy, WA. Other producers were Lassenite Industries Inc. in Herlong, CA; Cyprus Minerals Co. (formerly Cyprus Diatomite Co., a division of Amoco Minerals Co.) in Fernley, NV; and Oil-Dri Production Co. in Christmas Valley, OR.

Eagle-Picher, Reno, NV, began development of its open pit diatomite operation near Drewsey, Harney County, OR, in late 1985. Mining and processing was expected to be on-stream in mid-1986. The processing plant is near Vale in Malheur County, OR.

Grefco, Torrance, CA, began construction of a plant near Burney to process diatomite from the company's Shasta County, CA, freshwater deposits. The plant is expected to be completed by mid-1986. Initial plant capacity will be about 50,000 tons per year.

Whitecliff Industries was reported to have begun mining and shipping diatomite at Mammoth (near Tucson), AZ, in late 1985.

## CONSUMPTION AND USES

Apparent domestic consumption of processed diatomite increased slightly to 520,000 tons. Domestic and export sales of filter-grade diatomite were 417,000 tons, compared with 418,000 tons in 1984. Sales of filler-grade diatomite were 137,500 tons, slightly above that of 1984. Diatomite used as additives and absorbents increased 10,000 tons to 76,000 tons. Insulation use decreased 35% to 4,200 tons in 1985, the second straight year of decline.

### Table 2.—Diatomite sold or used,[1] by principal use

(Percent of U.S. production)

| Use | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Fillers | 23 | 19 | 21 | 22 | 21 |
| Filtration | 64 | 68 | 66 | 67 | 66 |
| Insulation | 2 | 1 | 3 | 1 | 1 |
| Other[2] | 11 | 12 | 10 | 10 | 12 |

[1] Includes exports.
[2] Includes abrasives (1981-82), absorbents, additives, and silicate admixtures.

## PRICES

The average unit value of sales for processed diatomite increased $7 per ton to $200.

### Table 3.—Average annual value per ton[1] of diatomite, by use

| Use | 1983 | 1984 | 1985 |
|---|---|---|---|
| Fillers | $176.77 | $175.10 | $184.49 |
| Filtration | 200.16 | 210.60 | 220.80 |
| Insulation | 119.26 | 136.98 | 110.95 |
| Other[2] | 116.05 | 120.85 | 118.39 |
| Weighted average | 184.58 | 192.62 | 199.93 |

[1] Based on unrounded data.
[2] Includes absorbents, additives, and silicate admixtures.

## FOREIGN TRADE

U.S. exports of processed diatomite declined 6% from that of 1984. Average unit value of exports, however, increased slightly from $232 per ton to $238 per ton. Diatomite was exported to 77 countries, and the quantity represented 19% of domestic production. The following six countries received 61% of the total: Canada, 25,500 tons; Japan, 14,000 tons; Australia, 13,000 tons; the United Kingdom, 8,700 tons; the Republic of South Africa, 6,100 tons; and the Federal Republic of Germany, 5,900 tons.

Diatomite imports totaled 4,950 tons, of which nearly 95% originated from Taiwan, compared with 338 tons in 1984, of which Mexico supplied 75%.

### Table 4.—U.S. exports of diatomite

(Thousand short tons and thousand dollars)

| Year | Quantity | Value[1] |
|---|---|---|
| 1982 | 141 | 29,863 |
| 1983 | 146 | 31,569 |
| 1984 | 127 | 29,461 |
| 1985 | 120 | 28,519 |

[1] U.S. Customs.

## WORLD REVIEW

World production of diatomite was estimated to be nearly 2 million tons, of which the United States produced one-third, followed by Romania, France, and the U.S.S.R. New data available in recent years show that Romania has emerged as a major world producer. The principal Romanian deposit areas are at Adamclisi, Partirlapele-Buzau, and Minis-Arad. Diatomite consumption in Romania has been oriented toward the building construction industry.

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[1] Industry economist, Division of Industrial Minerals.

### Table 5.—Diatomite: World production, by country[1]

(Thousand short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria[e] | 5 | 5 | 5 | 2 | 2 |
| Argentina | 5 | 7 | 12 | [e]11 | 12 |
| Australia | 2 | 2 | [e]9 | [e]9 | 9 |
| Brazil (marketable) | 10 | 14 | [e]18 | [e]18 | 18 |
| Canada[e] | 4 | 2 | 2 | 2 | 2 |
| Chile | (2) | (2) | 1 | 2 | 2 |
| Colombia[e] | 1 | 1 | 1 | 1 | 1 |
| Costa Rica | 1 | 1 | [e]1 | [e]1 | 1 |
| Denmark:[3] | | | | | |
| Diatomite | 4 | [r]4 | 7 | 18 | 6 |
| Moler | 70 | 78 | [r] [e]72 | 70 | 83 |
| Egypt | -- | -- | (2) | [e](2) | (2) |
| France | [r] [e]231 | 269 | 244 | 278 | 276 |
| Germany, Federal Republic of | 47 | 47 | 49 | 49 | 50 |
| Iceland | 22 | 23 | 28 | 30 | 33 |
| Italy[e] | 28 | 22 | 28 | [r]31 | 33 |
| Kenya | 2 | 2 | 2 | 2 | 2 |
| Korea, Republic of | 46 | 61 | 62 | 58 | 55 |
| Mexico | 62 | 62 | 48 | 49 | 50 |
| Peru[e] | 8 | 8 | 8 | 8 | 8 |
| Portugal | 3 | [e]3 | 2 | 2 | 2 |
| Romania[e] | [r]320 | [r]320 | [r]320 | [r]331 | 331 |
| South Africa, Republic of | 1 | 1 | 1 | (2) | (2) |
| Spain | 42 | 70 | 61 | 80 | 66 |
| Thailand | (2) | (2) | (2) | 1 | 1 |
| Turkey[e] | 11 | 11 | 11 | [r]3 | 3 |
| U.S.S.R.[e] | [r]254 | 260 | 260 | 265 | 270 |
| United Kingdom | [e]1 | [e]1 | (2) | (2) | (2) |
| United States | 687 | 618 | 619 | 627 | [4]635 |
| Total | [r]1,867 | [r]1,892 | 1,871 | 1,933 | 1,951 |

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through Apr. 22, 1986.
[2]Less than 1/2 unit.
[3]Data represent sales.
[4]Reported figure.

# Feldspar, Nepheline Syenite, and Aplite

## By Michael J. Potter[1]

Total U.S. feldspar output in 1985, including soda, potash, or mixed feldspar, and feldspar-silica mixtures, was 700,000 short tons with a value of $22.8 million. Housing and commercial construction activity remained relatively high resulting in continued strong demand for plumbing fixtures, tile, and glass fiber insulation in which feldspar is used. Imports of crude and ground nepheline syenite decreased 12% to about 333,000 tons with a total value of $11.4 million.

**Domestic Data Coverage.**—Domestic production data for feldspar are developed by the Bureau of Mines by means of a voluntary survey. Of the 15 active mines, 12, or 80%, responded, representing an estimated 81% of the total production data for feldspar shown in table 1. The remaining 19% was estimated from prior years' data adjusted to current industry levels.

**Legislation and Government Programs.**—According to provisions of the Tax Reform Act of 1969, which continued in force throughout 1985, the depletion rate allowed on domestic and foreign feldspar production was 14%.

**Table 1.—Salient feldspar and nepheline syenite statistics**

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Feldspar: | | | | | |
| Produced[1] short tons | 665,000 | 615,000 | 710,000 | 710,000 | 700,000 |
| Value thousands | $21,000 | $20,300 | $22,500 | $23,500 | $22,800 |
| Exports short tons | 14,025 | 10,800 | 9,360 | 10,080 | 9,280 |
| Value thousands | $1,110 | $989 | $856 | $920 | $680 |
| Imports for consumption short tons | 206 | 48 | 64 | 25 | 952 |
| Value thousands | $61 | $24 | $31 | $15 | $1,150 |
| Nepheline syenite: | | | | | |
| Imports for consumption short tons | 506,100 | 455,596 | 407,351 | 377,945 | 332,604 |
| Value thousands | $11,529 | $13,751 | $13,997 | $14,218 | $11,435 |
| Consumption, apparent[2] (feldspar plus nepheline syenite) thousand short tons | 1,157 | 1,060 | 1,108 | 1,078 | 1,024 |
| World: Production (feldspar) do | [r]3,561 | [r]3,835 | 4,008 | [p]4,167 | [e]4,294 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Includes hand-cobbed feldspar, flotation concentrate feldspar, and feldspar in feldspar-silica mixtures; includes potash feldspar (8% $K_2O$ or higher).

[2] Production plus imports minus exports.

## FELDSPAR

### DOMESTIC PRODUCTION

Soda feldspar is defined commercially as containing 7% soda ($Na_2O$) or higher; potash feldspar contains 10% potash ($K_2O$) or higher. However, to publish information on potash feldspar without revealing company proprietary data in this report, feldspars containing 8% $K_2O$ or more are defined as potash feldspars. Hand-cobbed or hand-sorted feldspar is usually obtained from pegmatites and is relatively high in $K_2O$

compared with $Na_2O$. Hand cobbing continued to be a minor fraction of total production. Feldspar flotation concentrates, most of the U.S. output, are classified as either soda, potash, or mixed feldspar, depending on the relative amounts of $Na_2O$ and $K_2O$ present. Feldspar-silica mixtures, feldspathic sand, can either be naturally occurring or a flotation product. Total feldspar content of this mixture was 28% of total feldspar output during 1985.

Feldspar was mined in six States, led by North Carolina and followed in descending order by Connecticut, Georgia, California, Oklahoma, and South Dakota. North Carolina accounted for 70% of the total. Eleven U.S. companies operating 15 mines and 18 plants produced feldspar or feldspar-silica mixtures for shipment to more than 31 States and foreign countries, primarily Canada and Mexico. Of the 11 companies, 3 produced potash feldspar, and the remainder produced mixed feldspar or feldspathic sand mixtures. North Carolina had five plants, California had three, and Connecticut, Georgia, South Carolina, and South Dakota each had one.

The data for potash feldspar were collected from the three U.S. producers of this material; some of this feldspar contained less than 10% $K_2O$ (8% to 10% $K_2O$).

Lithium Corp. of America (Lithco), a wholly owned subsidiary of Gulf Resources & Chemical Corp., was sold to FMC Corp.[3] Lithco's domestic facilities are located near Bessemer City, NC. Ore from the company's open pit mine was milled to produce lithium-bearing spodumene concentrates, byproduct mica, and feldspar-silica mixtures.

### Table 2.—Feldspar[1] produced in the United States

(Thousand short tons and thousand dollars)

| Year | Hand-cobbed | | Flotation concentrate | | Feldspar-silica mixtures[2] | | Total[3] | |
|---|---|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| 1981 | 11 | 194 | 504 | 16,850 | 149 | 4,000 | 665 | 21,000 |
| 1982 | 10 | 172 | 457 | 16,090 | 147 | 4,040 | 615 | 20,300 |
| 1983 | 7 | 107 | 525 | 17,128 | 178 | 5,265 | 710 | 22,500 |
| 1984 | 7 | 124 | 502 | 17,874 | 201 | 5,503 | 710 | 23,500 |
| 1985 | 14 | W | 487 | 16,781 | 197 | W | 700 | 22,800 |

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Includes potash feldspar (8% $K_2O$ or higher).

[2] Feldspar content.

[3] Data may not add to totals shown because of independent rounding.

### Table 3.—Producers of feldspar in 1985

| Company | Plant location | Product |
|---|---|---|
| Arkhola Sand & Gravel Co | Muskogee, OK | Feldspar-silica mixture. |
| California Silica Products Co | San Juan Capistrano, CA. | Do. |
| Calspar Inc | Santa Fe Springs, CA | Soda feldspar. |
| Crystal Silica Co. | Oceanside, CA | Feldspar-silica mixture. |
| The Feldspar Corp | Middletown, CT | Soda feldspar. |
| Do | Monticello, GA | Potash feldspar. |
| Do | Spruce Pine, NC | Soda feldspar. |
| Do | Montpelier, VA | Aplite. |
| Foote Mineral Co | Kings Mountain, NC | Feldspar-silica mixture. |
| Indusmin Inc | Spruce Pine, NC | Soda feldspar. |
| International Minerals & Chemical Corp | do | Do. |
| Kings Mountain Mica Co. Inc | Kings Mountain, NC | Potash feldspar. |
| Lithium Corp. of America | Bessemer City, NC | Feldspar-silica mixture. |
| Pacer Corp | Custer, SD | Potash feldspar. |
| Spartan Minerals Corp. | Pacolet, SC | Feldspar-silica mixture. |

## CONSUMPTION AND USES

The majority of users acquired their supplies already ground and sized by feldspar producers, although some manufacturers of pottery, soaps, and enamels continued to purchase feldspar for grinding to their preferred specifications in their own mills. A substantial portion of the material classified as feldspar-silica mixtures served in glassmaking without additional processing.

Of the total feldspar consumed in the United States, 55% was used in glassmaking, including container glass and glass fiber; 45% was used in pottery; and less than 1% was used in enamels, electrical insulators, etc.

The use of feldspar in pottery articles such as plumbing fixtures and tile increased by 9% compared with that of 1984. This was apparently because of the continued good demand for plumbing fixtures and tile in the housing market.

### Table 4.—Destination of shipments of feldspar[1] sold or used by producers in the United States, by State

(Short tons)

| State | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Alabama | 19,600 | 16,500 | 14,600 | 15,100 | W |
| California[e] [2] | 35,000 | 30,000 | 45,000 | 45,000 | 50,000 |
| Connecticut | 17,800 | 18,800 | W | W | W |
| Florida | 25,700 | 21,000 | 22,700 | 20,300 | 16,900 |
| Georgia | 68,300 | 74,600 | 96,900 | 96,000 | 95,300 |
| Illinois | 31,100 | 26,900 | 46,600 | 38,000 | 37,000 |
| Indiana | 22,700 | 20,200 | 37,200 | [r]35,700 | W |
| Kentucky | 11,700 | 13,400 | 11,400 | 13,300 | 16,200 |
| Louisiana | 13,900 | 12,200 | 17,400 | 21,300 | 12,200 |
| Maryland | 4,300 | 4,600 | 4,500 | 7,400 | 7,400 |
| Massachusetts | 8,800 | 9,300 | 1,200 | [r]10,800 | W |
| Michigan | W | 2,000 | W | W | W |
| Mississippi | 13,000 | 15,800 | 15,900 | 12,000 | W |
| Missouri | 4,300 | 4,100 | 5,000 | 4,400 | 4,700 |
| New Jersey | 63,400 | 51,700 | 56,600 | 53,200 | W |
| New York | 19,400 | 17,800 | 18,300 | [r]10,800 | W |
| North Carolina | 17,000 | 16,500 | 20,100 | 16,400 | 17,000 |
| Ohio | 52,800 | 51,600 | 53,600 | [r]64,900 | 65,800 |
| Oklahoma | 34,700 | 31,900 | W | W | W |
| Pennsylvania | 42,900 | 28,800 | 33,200 | [r]37,200 | 31,100 |
| South Carolina | 16,400 | 14,900 | 18,400 | 17,400 | W |
| Tennessee | 16,100 | 15,300 | W | W | W |
| Texas | 39,400 | 36,700 | 41,900 | [r]41,400 | 42,000 |
| West Virginia | 36,100 | 31,600 | 38,100 | [r]28,500 | 27,000 |
| Wisconsin | W | W | 9,400 | 11,100 | W |
| Other destinations[3] | 40,600 | 43,800 | 102,000 | [r]99,800 | 277,400 |
| **Total** | **655,000** | **610,000** | **710,000** | **[r]700,000** | **700,000** |

[e] Estimated. [r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other destinations."

[1] Includes potash feldspar (8% $K_2O$ or higher).

[2] Data are incomplete, and estimates are very rough.

[3] Includes Arkansas, Colorado, Kansas, Minnesota, Rhode Island, Virginia, States indicated by symbol W, and unspecified States. Also includes exports to Canada, Mexico, and other foreign countries.

## Table 5.—Destination of shipments of potash feldspar[1] sold or used by producers in the United States

(Short tons)

| Destination | 1981 | 1982 | 1983 | 1984[r] | 1985 |
|---|---|---|---|---|---|
| Illinois, Indiana, Wisconsin | 11,300 | 8,000 | 6,000 | 5,800 | 5,800 |
| Maryland, New York, West Virginia | 24,800 | 21,600 | 25,300 | 21,800 | 28,000 |
| Ohio | 9,800 | 8,100 | 8,100 | 9,000 | 8,200 |
| Pennsylvania | 9,100 | 6,400 | 7,100 | 13,500 | 8,200 |
| Texas | 200 | 200 | 300 | 200 | 200 |
| Canada | 4,900 | 3,200 | 4,300 | 4,600 | 5,200 |
| Mexico | 2,800 | 2,400 | W | W | W |
| Other[2] | 17,500 | 16,300 | 14,100 | 16,400 | 21,400 |
| Total | 80,400 | 66,200 | 65,200 | 71,300 | 77,000 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] $K_2O$ content of 8% or higher.

[2] Includes Alabama, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Kansas, Kentucky, Michigan, Massachusetts, Minnesota, Missouri, New Jersey, North Carolina, South Carolina, Tennessee, States indicated by symbol W, and other unspecified States. May also include foreign countries.

## Table 6.—Feldspar[1] sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

| Use | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Hand-cobbed: | | | | |
| Pottery | 6 | 487 | 12 | W |
| Other | 1 | 51 | 1 | W |
| Total | 7 | 538 | 13 | W |
| Flotation concentrate: | | | | |
| Glass | 229 | 7,063 | 216 | 7,207 |
| Pottery | [r]253 | [r]12,100 | 276 | 14,135 |
| Other | W | W | -- | -- |
| Total | W | W | 492 | 21,342 |
| Feldspar-silica mixtures:[2] | | | | |
| Glass | 153 | 7,468 | 173 | 8,351 |
| Pottery | 28 | 1,367 | 25 | W |
| Other | W | W | -- | -- |
| Total | W | W | 198 | W |
| Total:[3] | | | | |
| Glass[4] | 382 | 14,531 | 389 | 15,558 |
| Pottery | [r]287 | [r]13,954 | 313 | W |
| Other[5] | [r]28 | [r]1,568 | 1 | W |
| Total | [r]700 | [r]30,100 | 700 | 32,000 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Includes potash feldspar (8% $K_2O$ or higher).

[2] Feldspar content.

[3] Data may not add to totals shown because of independent rounding.

[4] Includes container glass and glass fiber.

[5] Includes enamel, filler, etc., and unknown.

## Table 7.—Potash feldspar[1] sold or used by producers in the United States, by use

| Use | 1984[r] | | 1985 | |
|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Pottery | 52,200 | $3,790 | 59,300 | W |
| Other[2] | 19,100 | 990 | 17,700 | W |
| Total | 71,300 | 4,780 | 77,000 | W |

[r] Revised. W Withheld to avoid disclosing company proprietary data.

[1] $K_2O$ content of 8% or higher.

[2] Includes glass, enamel, etc.

## PRICES

Most feldspar prices increased compared with those of 1984. Engineering and Mining Journal, December 1985, listed the following prices for feldspar, per short ton, f.o.b. mine or mill, carload lots, bulk, depending on grade:

| | 1984 | 1985 |
|---|---|---|
| Connecticut: | | |
| 20 mesh, granular | $39.00 | $41.35 |
| 200 mesh | 53.25 | 56.50 |
| Georgia: | | |
| 40 mesh, granular | 54.00 | 57.25 |
| 200 mesh | 73.50 | 76.50 |
| North Carolina: | | |
| 20 mesh, flotation | 29.25 | 29.25 |
| 40 mesh, flotation | 54.00 | 57.25 |
| 200 mesh, flotation | NA | 76.50 |

NA Not available.

Source: Engineering and Mining Journal, v. 186, No. 12, Dec. 1985, p. 11.

## FOREIGN TRADE

U.S. exports classified as feldspar, leucite, and nepheline syenite, but presumably mostly feldspar, decreased 8% to 9,280 tons valued at $680,000. Chief recipients were Canada, 51%; the Dominican Republic, 18%; Mexico, 11%; and Taiwan, 6%. The remaining 14% was shared among eight other countries.

In addition to feldspar and nepheline syenite, the United States imported 580 tons of "Other mineral fluxes, crushed" with a value of $323,000. This represented a 59% decrease in tonnage compared with that of 1984. Also, 60,400 tons of "Other crude natural mineral fluxes" was imported with a value of about $3.0 million. This was a 39% decrease in tonnage compared with that of 1984.

The tariff schedule in force throughout 1985 for most favored nations provided for a 3.0% ad valorem duty on ground feldspar; imports of unground feldspar were admitted duty free.

### Table 8.—U.S. exports of feldspar, by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Short tons | Value | Short tons | Value |
| Canada | 6,040 | $378,100 | 4,700 | $290,100 |
| Dominican Republic | 1,020 | 107,400 | 1,640 | 100,300 |
| Mexico | 1,180 | 179,400 | 1,000 | 54,800 |
| Philippines | 270 | 27,100 | -- | -- |
| Taiwan | 600 | 112,000 | 560 | 100,400 |
| Venezuela | 490 | 38,300 | 270 | 60,000 |
| Other | 480 | 77,400 | 1,110 | 74,100 |
| Total | 10,080 | 919,700 | 9,280 | 679,700 |

Source: Bureau of the Census.

**Table 9.—U.S. imports for consumption of feldspar, by type and country**

| Type and country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Short tons | Value | Short tons | Value |
| Crude: |  |  |  |  |
| Canada | -- | -- | 20 | $9,000 |
| Germany, Federal Republic of | 1 | $361 | -- | -- |
| Mexico | -- | -- | 214 | 19,328 |
| United Kingdom | 1 | 561 | -- | -- |
| Venezuela | -- | -- | 702 | 1,097,600 |
| Ground, crushed, or pulverized: |  |  |  |  |
| France | 11 | 9,800 | -- | -- |
| Germany, Federal Republic of | 2 | 227 | -- | -- |
| Netherlands | -- | -- | 9 | 19,116 |
| Switzerland | -- | -- | 1 | 2,428 |
| United Kingdom | 10 | 3,595 | 6 | 2,991 |
| Total | 25 | 14,544 | 952 | 1,150,463 |

Source: Bureau of the Census.

## WORLD REVIEW

**Germany, Federal Republic of.**—Although a major producer of feldspar, the country relied on imports of feldspar and nepheline syenite from the Scandinavian countries. The majority of feldspar was used as a flux in the ceramics industry, of which the Federal Republic of Germany was a leading producer. The most important feldspar producing region contained feldspar-quartz-pegmatites and their derived pegmatite sands, which were mined and beneficiated in conjunction with kaolin and silica sand. Amberger Kaolinwerke GmbH was Western Europe's largest producer of potassium feldspar with about 130,000 tons per year. Gebruder Dorfner OHG had an output of about 28,000 tons per year of feldspar. The ceramic manufacturer Hutschenreuther AG also worked pegmatite sands and had an annual capacity of 44,000 tons of feldspar. Saarfeldspatwerke H. Huppert GmbH & Co. KG of Saarbrucken was mining 55,000 to 66,000 tons per year of feldspar. The country's largest tile manufacturer and major whiteware ceramic producer, Villeroy and Boch Keramisch Werke KG, worked partly kaolinized, feldspar-rich rhyolites and was producing about 55,000 tons per year of feldspar for its own consumption. Rhyolites are fine-grained igneous rocks having a chemical composition similar to that of granite. A final source of feldspathic material was phonolite, which is an igneous rock containing feldspar. The major producer of phonolite was the Brenk Mine at Eifel, operated by Kali Chemie AG. Annual production was approximately 140,000 tons, which was primarily for the manufacture of colored glass.[3]

**Greece.**—The Hellenic Industrial Development Bank reportedly began work on its feldspar mine at Paranesti near Drama. In the first stage, production was planned at a rate of 31,000 tons per year at an estimated cost of $2.7 million. Upon completion of the facility, annual output was projected to rise to 86,000 tons. Greece imported up to 15,000 tons per year of feldspar during the previous decade.[4]

The final stage of construction for a plant owned by Dr. Georgiadis to process quartz and feldspar, and potentially other minerals, continued in 1985 at Assiros in northern Greece, approximately 15 miles north of Thessalonike. The feldspar was a soda feldspar occurring in pegmatite veins. Processing steps would be employed to remove mica and iron oxide. Quartz and feldspar would be sold for use in ceramics and paint. Feldspar sales would be directed at eastern and central Mediterranean countries and the Middle East, after satisfying local demand.[5]

**Spain.**—Industrias del Cuarzo S.A. continued mining operations at a large feldspathic sand deposit at Carrascal del Río in Segovia Province. The processing plant produced silica, feldspathic sand, and feldspar.

Llansa S.A. worked five quarries near Llansa in Gerona Province. The deposit was in the form of pegmatite veins, with three of the quarries containing soda feldspar and two containing mixed soda-potash feldspar. Proven reserves were in excess of 5 million tons. Processing steps included crushing, washing to separate clays, and air separation. Plant capacity was 44,000 tons per year. A second milling plant, which would include magnetic separation and air separators of a new design and would double capacity to 88,000 tons per year, was targeted to come on-stream at yearend 1985.[6]

**United Kingdom.**—Feldspar imports in 1984 were 60,000 tons. Principal countries of origin and the share supplied were Finland, 43%; Norway, 26%; and Sweden, 20%.[7]

### Table 10.—Feldspar: World production, by country[1]

(Thousand short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina | 29 | 17 | 22 | [e]22 | 22 |
| Australia | 4 | 5 | 4 | [e]4 | 4 |
| Austria | 11 | 3 | 1 | 3 | 3 |
| Brazil[3] | 181 | 145 | 136 | 116 | 132 |
| Burma | 5 | 3 | 3 | 7 | 7 |
| Chile | 3 | 1 | 3 | 3 | 3 |
| Colombia | 30 | 33 | 35 | 36 | 35 |
| Egypt | 4 | 9 | 7 | [e]6 | 6 |
| Finland | 70 | 77 | 57 | 62 | 61 |
| France | 211 | 191 | 193 | 230 | 231 |
| Germany, Federal Republic of | 377 | 365 | 364 | [r] [e]287 | 309 |
| Guatemala[e] | [4]11 | 13 | 7 | [r]6 | 6 |
| Hong Kong | 4 | 36 | 62 | 127 | 83 |
| India | 65 | 49 | 46 | 44 | 44 |
| Iran[e] | 2 | 3 | 3 | 3 | 3 |
| Italy | 472 | 864 | 951 | 1,086 | [4]1,231 |
| Japan[5] | 28 | 33 | 34 | 39 | 34 |
| Kenya | (6) | -- | 1 | 1 | 1 |
| Korea, Republic of | 114 | 94 | 121 | 140 | 110 |
| Mexico | 144 | 127 | 130 | 98 | 110 |
| Morocco | 2 | 1 | [e]1 | [e]1 | 1 |
| Mozambique | 1 | 1 | 1 | [e]1 | 1 |
| Nigeria[e] | 6 | 6 | 6 | 6 | 6 |
| Norway[7] | [r]64 | [r]69 | 64 | [r] [e]66 | 66 |
| Pakistan | 12 | [r]9 | 6 | 6 | 6 |
| Peru[e] | [4]24 | 28 | 28 | 28 | 28 |
| Philippines | 18 | 17 | 7 | 13 | 13 |
| Poland[e] | 90 | 88 | 88 | 88 | 88 |
| Portugal[e] | [4]49 | 47 | 46 | 44 | 39 |
| Romania[e] | [r]93 | [r]93 | [r]94 | [r]94 | 95 |
| South Africa, Republic of | 63 | 58 | 50 | 43 | 35 |
| Spain[8] | 143 | 144 | 128 | [e]127 | 132 |
| Sri Lanka | [e]4 | 3 | 3 | 6 | 6 |
| Sweden | 44 | 60 | 58 | [e]61 | 61 |
| Taiwan | 19 | 12 | 13 | 17 | 17 |
| Thailand | 27 | 21 | 58 | 82 | 83 |
| Turkey[e] | 77 | 77 | [4]10 | 11 | 22 |
| U.S.S.R.[e] | 350 | 360 | 360 | 360 | 370 |
| United Kingdom (china stone) | [r]6 | [r]6 | 7 | 7 | 7 |
| United States | 665 | 615 | 710 | 710 | [4]700 |
| Uruguay | 3 | 1 | 1 | [e]1 | 1 |
| Venezuela | 24 | [e]8 | 41 | [r] [e]32 | 31 |
| Yugoslavia | 59 | 47 | 46 | [e]46 | 50 |
| Zambia | (6) | (6) | (6) | (6) | (6) |
| Zimbabwe | 3 | 1 | 2 | 2 | 1 |
| Total | [r]3,561 | [r]3,835 | 4,008 | 4,167 | 4,294 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through May 6, 1986.

[2] In addition to the countries listed, Czechoslovakia, Madagascar, and Namibia produce feldspar, but output is not officially reported, and available general information is inadequate for the formulation of reliable estimates of output levels.

[3] Series excludes production of leucite and sodalite; data consist only of that material reported by Brazil under the heading of "Feldspar." Data represent the sum of (1) run-of-mine production for direct sale and (2) salable beneficiated product; total run-of-mine feldspar production was as follows, in thousand short tons: 1981—121 (revised); 1982—87; 1983—71 (revised); 1984—93; and 1985—100 (estimated).

[4] Reported figure.

[5] In addition, the following quantities of aplite were produced, in thousand short tons: 1981—336; 1982—335; 1983—442 (revised); 1984—486; and 1985—515 (estimated).

[6] Less than 1/2 unit.

[7] Excludes nepheline syenite.

[8] Includes pegmatite.

## NEPHELINE SYENITE

Nepheline syenite is a quartz-free, light-colored rock that, although resembling medium-grained granite in texture, consists principally of nepheline and alkali feldspars, usually in association with minor amounts of other minerals. Large quantities of nepheline syenite, after processing to remove contaminants, especially iron-bearing minerals, were consumed in making glass and ceramics. There was no domestic production of nepheline syenite in grades suitable for these purposes, and U.S. needs were wholly supplied by imports.

With the purchase of IMC Industry

Group (Canada) Ltd. in 1985, Falconbridge Ltd. became owner of both nepheline syenite operations in Canada. The two operations, IMC and Indusmin Ltd., a division of Falconbridge, were mined at different points on the Nephton nepheline syenite deposit in the Blue Mountain District of Ontario, Canada.[8]

In Norway, nepheline syenite was produced at the Norsk Nefelin underground mining operation on the Arctic island of Stjernoy. Sales were mostly to markets in Western Europe.

About two-thirds of the output from Canada and Norway was consumed in insulation fiberglass and container glass manufacture. The second largest outlet was in ceramics, especially porcelain, tile, and whitewares. Nepheline syenite also was used in fine-grind applications as an extender in paint and an inert filler in plastics.[9]

In the U.S.S.R., development of the mineral resource known as synnyrite was being considered. The mineral, which has been identified in only two locations in Siberia, is similar to nepheline syenite and is made up essentially of the potassium analog of nepheline-kalsilite, $K_2O \cdot Al_2O_3 \cdot 2SiO_2$; and potassium feldspar, $K_2O \cdot Al_2O_3 \cdot 6SiO_2$. Synnyrite is a potential raw material for the production of alumina for reduction to aluminum and nonchlorine-containing potassium fertilizers. The typical composition of synnyrite is $SiO_2$, 54%; $Al_2O_3$, 22%; and $K_2O$, 19%. Various technologies for processing the mineral were being tested, including one that uses sulfuric acid to decompose the synnyrite into alum, $KAl(SO_4)_2$, and silica, $SiO_2$.[10]

The price for Canadian nepheline syenite, glass grade, bulk, 30 mesh, carlots or trucklots, was $20 to $28 per ton, depending on iron content, according to Industrial Minerals (London), December 1985.

**Table 11.—U.S. imports for consumption of nepheline syenite**

| Year | Crude | | Ground | |
|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1983 | 212 | $13 | 407,139 | $13,984 |
| 1984 | 410 | 17 | 377,535 | 14,201 |
| 1985 | 920 | 62 | 331,684 | 11,373 |

Source: Bureau of the Census.

## APLITE

Aplite is a feldspar mineral that has more than one geological definition. However, aplite from the only active U.S. operation contains primarily lime-soda feldspar. Aplite, usually unsuitable for use in ceramics, has been used in the manufacture of glass, especially container glass, when it is sufficiently low in iron. Japan, with an annual production of approximately 450,000 tons, has been the world's foremost producer of aplite.

Aplite of glassmaking quality was produced in the United States from one surface mine. The Feldspar Corp. mined aplite near Montpelier, Hanover County, VA, and treated the material by wet grinding, classification, and spiraling to remove biotite, ilmenite, and rutile, followed by dewatering and high-intensity magnetic separation to eliminate iron-bearing minerals.

Domestic output of aplite increased over that of 1984. The data are company proprietary and cannot be released for publication. Aplite traditionally has a somewhat lower price than feldspar. Industrial Minerals (London), December 1985, gave a value of $25.75 per ton for glass grade, bulk, 100% plus 200 mesh, f.o.b. Montpelier, VA.

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[1] Physical scientist, Division of Industrial Minerals.

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[3] Robbins, J. The Industrial Minerals of West Germany. Ind. Miner. (London), No. 219, Dec. 1985, p. 39.

[4] Mining Journal (London). Paranesti Feldspar for Greece. V. 304, No. 7795, Jan. 11, 1985, p. 26.

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[6] ———. Spain's Industrial Minerals. Ind. Miner. (London), No. 217, Oct. 1985, p. 46.

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[9] Ash, D. R. Nepheline Syenite. Min. Eng., v. 37, No. 5, May 1985, p. 477.

[10] Soviet Geography. Potential Uses of Synnyrite Being Studied. V. 26, Jan. 1985, p. 64.

# Ferroalloys

## By Raymond E. Brown[1]

World demand for ferroalloys in 1985 was little changed from that of 1984. As a result, prices for most ferroalloys remained depressed. Brazil planned to triple its ferroalloy production capacity despite world overcapacity and oversupply conditions. The expansion in Brazil is being offset to some extent by reductions in the United States and Japan. The European Economic Community's (EEC) Executive Commission voted against allowing the official formation of Euromang, a cartel consisting of EEC ferromanganese producers. The EEC also increased tariff quotas on certain duty-free ferroalloy imports and approved a plan to support research on ways to make its mining and materials industries more competitive. Although France, the United Kingdom, and the United States reduced or planned to reduce the size of their stockpiles, Japan planned to increase its stockpile, and the Republic of Korea planned to initiate a stockpiling program. The Government of Japan agreed to provide tax credits for expenditures by its ferrochromium producers for modernization or research and development. The Government of the Republic of South Africa was considering withholding exports of chromium in retaliation for tougher U.S. sanctions. The high value of the U.S. dollar relative to other currencies continued to make the United States an attractive market for exporters throughout the world. However, the administration took steps to weaken the U.S. dollar.

**Domestic Data Coverage.**—Domestic production data for ferroalloys are developed by the Bureau of Mines by means of monthly and annual voluntary domestic surveys. Typical of these surveys are the three separate monthly surveys for chromium alloys and metal, manganese alloys and metal, and silicon alloys and metal, and the annual survey for ferroalloys. Of the 51 operations to which a survey was sent, 44 responded, representing an estimated 90% of the total production and/or shipments shown in table 2. Production and shipments for the remaining seven nonrespondents were estimated using reported prior year production and shipment levels adjusted by trends in employment and other guidelines.

**Legislation and Government Programs.**—There were a number of significant Government actions that impacted the ferroalloys industry in 1985. For the third consecutive year, to begin in 1986, the General Services Administration awarded contracts to Macalloy Inc., Charleston, SC, and Elkem Metals Co., Pittsburgh, PA, for upgrading chromium ore and manganese ore, respectively, in the National Defense Stockpile to the ferroalloy form. Macalloy's contracts amounted to $22.7 million in 1984 to convert 125,628 short tons of chromite ore into 50,254 tons of high-carbon ferrochromium (H-C FeCr), $26.0 million in 1985 to convert 141,601 tons of ore into 56,640 tons of H-C FeCr, and $19.3 million in 1986 to convert 92,184 tons of ore into 38,200 tons of H-C FeCr. Elkem Metal's contracts amounted to $10.1 million in 1984 to convert 47,951 tons of manganese ore into 24,332 tons of high-carbon ferromanganese (H-C FeMn), $19.3 million in 1985 to convert 88,329 tons of ore into 46,620 tons of H-C FeMn, and $15.3 million in 1986 to convert 58,557 tons of ore into 34,200 tons of H-C FeMn. The 10-year upgrading program was designed to reduce the quantity of ore needing conversion to ferroalloy form during a national emergency and to help maintain an adequate level of U.S. ferroalloy furnace and processing capacity.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines for the chemical and metallurgical group, chromium would be categorized in tiers I and II, and the goals would be 199,300 tons and 594,123 tons, respectively, of chromium metal equivalent. Manganese would be categorized in tier II only, and the goal would be 869,667 tons of manganese metal equivalent. The reader is referred to the respective commodity chapters for more details on chromium and manganese and for information on other elements such as vanadium that are contained in the National Defense Stockpile. At yearend, this proposal was under consideration by the U.S. Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

Companion bills S. 262 and H.R. 976 entitled "Fair Trade in Ferroalloys Act" were introduced in the U.S. Senate on January 24 and in the U.S. House of Representatives on February 6. The bills, designed to preserve the domestic ferroalloy industry, would establish a tariff mechanism whereby certain ferroalloy imports entering the United States below an established fair market price would be automatically assessed a tariff. By yearend, the bills still were under consideration. On May 21, the U.S. Senate adopted an amendment (No. 168) to the U.S. Department of Defense (DOD) fiscal year 1986 authorization bill (S. 1160) that requires DOD to conduct a study to determine what impact the loss of all domestic ferroalloy production capacity would have on the U.S. industrial base and military preparedness.

Economic sanctions were proposed by members of the U.S. Congress against the Republic of South Africa in 1985 to protest that country's apartheid policy. Some of the proposed bills would have a direct impact on a wide range of minerals for which the Republic of South Africa is a leading supplier to the United States. For instance, H.R. 997, introduced in the U.S. House of Representatives on February 6, would prohibit U.S. citizens from making or holding any investments in the Republic of South Africa and would prohibit imports of materials such as ferrochromium, ferromanganese, and their respective ores from that country. H.R. 3481, introduced on October 2, would ban the importation of H-C FeCr from the Republic of South Africa into the customs territory of the United States. Although the bill would prohibit imports of South African H-C FeCr, it would not ban imports of chromite, the ore from which ferrochromium is smelted. The United States has no domestic reserves of chromite but has underutilized furnace processing capacity for conversion of ore to ferroalloy form.

Bill S. 1533, "National Security Trade Act of 1985," was introduced in the U.S. Senate on July 31 to amend section 232 of the 1962 Trade Expansion Act. The U.S. Trade Representative would have final responsibility for decisions on trade relief cases and setting time limits. On October 9, bill S. 1753 was introduced in the U.S. Senate to amend title II of the Trade Act of 1974 to eliminate the discretion of the President to grant import relief and for other purposes. The Administration has outlined a group of six top administration officials that would monitor other countries' export barriers to U.S. goods and unfair subsidies of foreign goods that compete in the U.S. market. The Administration also announced an agreement by the United States with four other leading industrial nations (France, the Federal Republic of Germany, Japan, and the United Kingdom) on a joint action to weaken the U.S. dollar in an attempt to slow the protectionist pressures on Congress to curb imports and to promote U.S. exports.

A "Buy America" clause in the Federal Government's procurement code, requiring that all purchases of chromium metal for stockpile purposes be made from the domestic industry, is under review by the office of the U.S. Trade Representative to determine if it can be instituted in the face of U.S. obligations under international Government procurement agreements. The Federal Emergency Management Agency requested the clause in an effort to maintain the domestic industry for defense purposes. Elkem Metals is the sole domestic producer of the vacuum-grade electrolytic chromium metal required for the stockpile. A review of defense-related ferrochromium procurement policy, instituted in 1984, and action to enforce the policy was called for by a member of the Senate Armed Services Committee.

The new National Critical Materials Council, consisting of three members nominated by the President, was sworn in on November 8. The Council will coordinate Government policies toward the mining and mineral processing industries.

Both the U.S. House of Representatives and the U.S. Senate passed Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) reauthorization bills but, by yearend, were unable to reconcile their differences. The House version would provide $10 billion for the program, while the Senate's measure would provide $7.5 billion. The legislative authority for taxes to pay for the cleanup of abandoned toxic chemical dumps expired on September 30, 1985. The Environmental Protection Agency (EPA) announced its intention to list chromium as a hazardous air pollutant for purposes of regulation under section 112 of the Clear Air Act. EPA is considering regulating some metal wastes that previously were excluded from regulation under the Resource Conservation and Recovery Act. Metal waste controls of this type are expected to impact domestic ferroalloy producers, among others.

The Congressional Research Service of the Library of Congress released a report that examines key changes in the structure of the U.S. ferroalloys industry since the early 1970's. The main focus is on the changing competitive posture of domestic producers of ferrochromium, ferromanganese, and ferrosilicon, the so-called tonnage alloys.[2] The Bureau of Mines released a report that reviews technological alternatives for the conservation of strategic and critical materials. The review focuses on the extent to which technologically and economically feasible programs in substitution, improved processing practices, recycling, and design can achieve conservation of chromium, manganese, and other critical and strategic materials, and thus reduce U.S. vulnerability to interruptions of supply. In addition, supply-side options—domestic and foreign resources, ocean minerals, and stockpiles—are identified.[3]

**Table 1.—Government inventory of ferroalloys, December 31, 1985**

(Thousand short tons)

| Alloy | Stock-pile grade | Non-stock-pile grade | Total |
|---|---|---|---|
| Ferrochromium: | | | |
| High-carbon | [1]452 | 1 | 453 |
| Low-carbon | 300 | 19 | 319 |
| Ferrochromium-silicon | 57 | 1 | 58 |
| Ferrocolumbium (contained columbium) | .3 | .2 | .5 |
| Ferromanganese: | | | |
| High-carbon | [2]624 | -- | 624 |
| Medium-carbon | 29 | -- | 29 |
| Ferrotungsten (contained tungsten) | .4 | .6 | 1 |
| Silicomanganese | 24 | -- | 24 |

[1] This figure includes the estimated 50,000 tons of high-carbon ferrochromium produced under the National Defense Stockpile chromium ore conversion program in 1984, but does not reflect the estimated 57,000 tons produced in 1985.

[2] This figure includes the estimated 24,000 tons of high-carbon ferromanganese produced under the National Defense Stockpile manganese ore conversion program in 1984, but does not reflect the estimated 47,000 tons produced in 1985.

## DOMESTIC PRODUCTION

Domestic production and shipments of ferroalloys declined in 1985 because of weak demand by major consuming industries and continued competition from low-priced imports. Producers of the bulk ferroalloys of chromium, manganese, and silicon, and their respective metals operated their plants at about two-fifths of capacity, down slightly from that of 1984. The long-term trend continued toward greater reliance on imported ferroalloys, especially for ferrochromium and ferromanganese. The number of active domestic producers of ferroalloys was again reduced.

A. Johnson Metals Corp., Lionville, PA, began marketing electrolytic manganese metal produced in the Republic of South Africa by Manganese Metal Co. (Pty.) Ltd. (MMC). MMC was formed by the merger between Delta Manganese (Pty.) Ltd. (Deltamang) and Electrolytic Metal Corp. Pty. Ltd. (Emcor). A. Johnson is the sole European sales agent for MMC and is one of MMC's three U.S. agents. Demolition of one of Bethlehem Steel Corp.'s old "L" blast furnaces in Johnstown, PA, in October represents a potential loss of 240,000 tons of H-C FeMn capacity. The Johnstown blast furnace was the last of its kind dedicated to the production of H-C FeMn until it was idled in 1977 because of flood damage. An important aspect of emergency plans for ferroalloy production in a national crisis has been reactivation of old blast furnaces for H-C FeMn production to free up submerged arc electric-furnace (SAEF) capacity for H-C FeCr production. Demolition of the Johnstown blast furnace eliminates the option of freeing up 240,000 tons of H-C FeMn SAEF capacity to produce approximately 140,000 tons of H-C FeCr. Cabot Corp., Boston, MA, announced a major restructuring program on October 16. The divestiture includes the sale of most of the company's metals businesses with the exception of its columbium and tantalum KBI Div. Bomar Resources Inc., New York, NY, was named the exclusive U.S. agent for Hellenic Ferroalloys S.A. (HFA).

Elkem A/S, Norway, increased to 100% its ownership of both Elkem Metals in the United States and Elkem Metals Canada Inc. in Canada. This completed the takeover begun in 1983 of bulk ferroalloy businesses in North America formerly owned by Union Carbide Corp. In August, hourly workers struck Elkem Metals' ferroalloy plant in Marietta, OH, for 1 month before an agreement was reached on a new contract. The Marietta plant produces high-purity chromium metal, manganese metal, manganese ferroalloys, and some vanadium products. A Government-funded retraining program in progress at Elkem Metals' Alloy, WV, plant was anticipated to give the ferroalloys producer an edge on foreign competition. Foote Mineral Co., Exton, PA, closed its Graham, WV, plant on December 31, putting nearly 300 people out of work. The workers had given concessions to the company in 1983 to help keep the plant operating. The company attributed the decision to close the plant to competition from large volumes of imported ferroalloys and to the higher production costs at Graham compared with its other plants. Sale of its specialty foundry product lines including proprietary technology, trade names, and patents to SKW Alloys Inc., Niagara Falls, NY, was to be effective on January 3, 1986. As compensation, Foote will participate in the profits obtained by SKW Alloys in the manufacture and sales of the specialty product lines over the next 6 years. Foote also was aiming to negotiate favorable labor and power contracts at its Keokuk, IA, plant by mid-1986. The company warned that failure to lower both labor and power costs would likely lead to closure of that plant.

Globe Metallurgical Inc., a subsidiary of Moore McCormack Resources Inc., reportedly was considering ending ferrochromium production at its Beverly, OH, plant. M. A. Hanna Co. obtained a 5-year extension of its current offpeak power rate from the Bonneville Power Administration for its Riddle, OR, ferronickel operation. Hanna also obtained a new 5-year labor contract. Subsequently, the Riddle facility was shut down for about 6 months for capital improvements that included a wet-screening system to upgrade the ore. Exports to Europe and Japan could account for up to 40% of Hanna's sales from its Riddle, OR, ferronickel plant. International Minerals & Chemical Corp., Northbrook, IL, completed an expansion that tripled production of high-purity quartz at its feldspar beneficiation complex in Spruce Pine, NC.

In February 1985, Ohio Ferro-Alloys Corp., Dayton, OH, closed its Powhatan Point silicon metal plant for the balance of the year. The company subsequently concentrated all of its silicon metal production at its Montgomery, AL, facility. The company's third plant in Philo, OH, which produced ferrosilicon, was shut down in September 1984. Ohio Ferro-Alloys also obtained a 5-year agreement to sell silicon metal from its Montgomery, AL, plant to General Electric Co.'s (GE) Silicones Product Div. and concluded a $3 million loan agreement with GE's Credit Corp.

Satra Concentrates Inc. was processing ferrochrome slags at its Steubenville, OH, plant. The company bought the slags and the equipment for treating them from Satralloy Inc., Steubenville, OH, a division of Satra Corp., New York, NY. Satralloy has not operated its six ferrochrome furnaces since November 1982. The furnaces had a combined annual capacity of 96,000 tons consisting of 36,000 tons of charge chrome, 36,000 tons of low-carbon ferrochromium, and 24,000 tons of ferrochromium-silicon. Satra Concentrates' water concentrator recovers about 80% of the charge chrome (60% to 65% chromium) from its first slag pile that originally contained about 5% charge chrome. Its magnetic reclamation system gets back approximately 70% of the low-carbon ferrochromium from its second slag pile that originally contained about 3% low-carbon ferrochromium (67% to 75% chromium). Satra Concentrates expects to be active over the next 5 years processing an estimated 175,000 tons of charge chrome slags and about 1 million tons of low-carbon ferrochromium slags. This is equivalent to an annual recovery from the slag piles of 1,400 tons of charge chrome and 4,000 tons of low-carbon ferrochromium.

SKW Alloys announced that it would cease production, but not marketing, of manganese ferroalloys at its Calvert City, KY, plant after current ore stocks are consumed. Trans World Metals Inc., New York, NY, was phasing out its ferroalloys trading business only about 1 year after it created a new division from the former ferroalloy division of Clarendon Ltd. Reportedly, the reason for withdrawing from the ferroalloys trading business was that the company considered itself an arbitrage trader and would need a whole new network to be an effective trader of ferroalloys.

After 2 years of attempting to sell Umetco Minerals Corp.'s metals mining and processing operations as an intact unit, Union Carbide, the parent company, announced that it will sell the operations piecemeal. The corporation agreed to sell the South African chromium assets of Umetco to General Mining Union Corp. Ltd. (Gencor) of the Republic of South Africa, Union Carbide's joint venture partner in Tubatse Ferrochrome (Pty.) Ltd. Gencor agreed to buy Umetco's 49% interest in Tubatse Ferrochrome, as well as all of Union Carbide's interests in Jagdlust Chrome Co. Pty. Ltd., Chrometco Minerals Pty. Ltd., and Chrome Corp. (South Africa) (Pty.) Ltd. With these purchases, Gencor would become a major force in the worldwide ferroalloys industry, rivaling Middleburg Steel & Alloys Holdings (Pty.) Ltd., Republic of South Africa, as one of the world's major ferrochrome producers. Employees of Umetco planned to acquire the company's U.S. tungsten and vanadium assets, which consist of tungsten mines at Bishop, CA, and Tempiute, NV, a vanadium mill and mine at Hot Springs, AR, and the tungsten and vanadium processing facilities at Niagara Falls, NY. They also planned to acquire the vanadium mine and mill at Brits in the Republic of South Africa. Union Carbide continued to negotiate with other organizations for the purchase of Umetco's major tungsten mine in Brazil and its significant interest in a major tungsten mine in Portugal, as well as its chromium mines and smelter in Zimbabwe.

Estimated ferrous scrap consumption by the domestic ferroalloys industry was 310,000 tons in 1985, down from 340,000 tons in 1984.

The Ferroalloys Association reported that its member companies consumed 4.5 billion kilowatt hours (kW•h) of electricity in 1985, down from 5.3 billion kW•h in 1984. Additionally, its member companies employed 4,100 workers and reported losses, before taxes, amounting to $16 million in 1985, compared with 4,800 (revised) workers and a reported profit amounting to $1 million in 1984.

**Table 2.—Ferroalloys[1] produced and shipped from furnaces in the United States**

| | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Net production | | Net shipments | | Net production | | Net shipments | |
| | Gross weight (short tons) | Alloy element contained (average percent) | Gross weight (short tons) | Value (thousands) | Gross weight (short tons) | Alloy element contained (average percent) | Gross weight (short tons) | Value (thousands) |
| Ferromanganese[2] | 171,129 | 77 | 185,499 | $106,282 | 153,550 | 77 | 156,582 | $100,903 |
| Silicomanganese | (3) | 66 | (3) | (3) | (3) | 66 | (3) | (3) |
| Manganese metal | (3) | 100 | (3) | (3) | (3) | 100 | (3) | (3) |
| Ferrosilicon[4] | 490,370 | 55 | 498,067 | 259,407 | 441,673 | 53 | 404,733 | 190,392 |
| Silicon metal | 140,866 | 98 | 139,393 | 171,814 | 120,965 | 99 | 121,640 | 157,231 |
| Chromium alloys: | | | | | | | | |
| Ferrochromium | 95,400 | 62 | 120,772 | 102,101 | 109,563 | 62 | 108,472 | 97,723 |
| Other[5] | (6) | -- | (6) | (6) | (6) | -- | (6) | (6) |
| Total | 95,400 | 62 | 120,772 | 102,101 | 109,563 | 62 | 108,472 | 97,723 |
| Ferrocolumbium | W | 65 | W | 9,809 | W | 65 | W | 8,843 |
| Ferrophosphorus | 91,117 | 24 | 113,504 | 18,123 | 61,962 | 24 | 54,912 | 7,921 |
| Other[7] | 99,010 | XX | 96,683 | 92,959 | 89,469 | XX | 95,360 | 136,179 |
| Grand total[8] | 1,087,892 | XX | 1,153,918 | 760,495 | 977,182 | XX | 941,698 | 699,191 |

W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable.

[1] Does not include alloys consumed in the making of other ferroalloys.

[2] Includes fused-salt electrolytic low- and medium-carbon ferromanganese (massive manganese), and includes silicomanganese and manganese metal.

[3] Included with ferromanganese.

[4] Includes miscellaneous silicon alloys.

[5] Includes ferrochromium-silicon, chromium briquets, exothermic chromium additives, other miscellaneous chromium alloys, and chromium metal.

[6] Included with ferrochromium.

[7] Includes ferroaluminum, ferroboron and other complex boron additive alloys, ferromolybdenum, ferronickel, ferrotitanium, ferrotungsten, ferrovanadium, ferrozirconium, silvery iron, and other miscellaneous alloys.

[8] Data may not add to totals shown because of independent rounding.

### Table 3.—Producers of ferroalloys in the United States in 1985

| Producer | Plant location | Products[1] | Type of furnace |
|---|---|---|---|
| FERROALLOYS (EXCEPT FERROPHOSPHORUS) | | | |
| Affiliated Metals and Minerals Inc | New Castle, PA | FeMo, FeV | Metallothermic. |
| Aluminum Co. of America, Northwest Alloys Inc. | Addy, WA | FeSi, Si | Electric. |
| Ashland Chemical Co | Columbus, OH | FeB, FeCb, FeMo, FeTi, FeW, NiCb. | Electric and metallothermic. |
| AMAX Inc., Climax Molybdenum Co. Div | Langeloth, PA | FeMo | Metallothermic. |
| Cabot Corp., KBI Div., Penn Rare Metal Div | Revere, PA | FeCb | Do. |
| Dow Corning Corp | Springfield, OR | Si | Electric. |
| Elkem A/S, Elkem Metals Co | Alloy, WV<br>Ashtabula, OH<br>Marietta, OH<br>Niagara Falls, NY | Cr, FeB, FeCr, FeMn, FeSi, Mn, Si, SiMn, other.[2] | Electric and electrolytic. |
| Foote Mineral Co., Ferroalloys Div | Cambridge, OH<br>Graham, WV<br>Keokuk, IA | FeSi, FeV, silvery pig iron, other.[2] | Electric. |
| Hanna Mining Co., The: | | | |
| Hanna Nickel Smelting Co | Riddle, OR | FeNi, FeSi | Do. |
| Silicon Div | Wenatchee, WA | FeSi, Si | Do. |
| International Minerals & Chemical Corp., Industry Group, TAC Alloys Div. | Bridgeport, AL<br>Kimball, TN | FeSi<br>FeSi, other[2] | Do.<br>Do. |
| Kerr-McGee Chemical Corp | Hamilton (Aberdeen), MS. | Mn | Electrolytic. |
| Macalloy Inc | Charleston, SC | FeCr | Electric. |
| Metallurg Inc., Shieldalloy Corp | Newfield, NJ | Cr, FeAl, FeB, FeCb, FeTi, FeV, other.[2] | Metallothermic. |
| Moore McCormack Resources Inc., Globe Metallurgical Inc. | Beverly, OH<br>Selma, AL | FeCr, Fesi, Si | Electric. |
| Ohio Ferro-Alloys Corp | Montgomery, AL<br>Powhatan Point, OH | FeSi, Si | Do. |
| Pennzoil Co., Duval Corp | Sahuarita, AZ | FeMo | Metallothermic. |
| Reactive Metals and Alloys Corp | West Pittsburg, PA | FeAl, FeB, FeTi, other[2] | Electric. |
| Reading Alloys Inc | Robesonia, PA | FeCb, FeV | Metallothermic. |
| Reynolds Metals Co | Sheffield, AL | Si | Electric. |
| SEDEMA S.A., Chemetals Corp | Kingwood, WV | FeMn | Fused-salt electrolytic. |
| SKW Alloys Inc | Calvert City, KY<br>Niagara Falls, NY | FeCr, FeCrSi, FeSi | Electric. |
| Teledyne Inc., Teledyne Wah Chang, Albany Div. | Albany, OR | FeCb | Metallothermic. |
| Umetco Minerals Corp | Marietta, OH<br>Niagara Falls, NY | FeV, FeW, other[2] | Electric. |
| Union Oil Co. of California, Molycorp Inc | Washington, PA | FeB, FeMo | Electric and metallothermic. |
| FERROPHOSPHORUS | | | |
| FMC Corp., Industrial Chemical Div | Pocatello, ID | FeP | Electric. |
| Monsanto Co., Monsanto Industrial Chemicals Co. | Columbia, TN<br>Soda Springs, ID | | |
| Occidental Petroleum Corp., Hooker Chemical Co., Industrial Chemicals Group. | Columbia, TN | | |
| Stauffer Chemical Co., Industrial Chemical Div. | Mount Pleasant, TN<br>Silver Bow, MT | | |

[1] Cr, chromium metal; FeAl, ferroaluminum; FeB, ferroboron; FeCb, ferrocolumbium; FeCr, ferrochromium; FeCrSi, ferrochromium-silicon; FeMn, ferromanganese; FeMo, ferromolybdenum; FeNi, ferronickel; FeP, ferrophosphorus; FeSi, ferrosilicon; FeTi, ferrotitanium; FeV, ferrovanadium; FeW, ferrotungsten; FeZr, ferrozirconium; Mn, manganese metal; Si, silicon metal; SiMn, silicomanganese.

[2] Includes specialty silicon alloys, zirconium alloys, and miscellaneous ferroalloys.

## CONSUMPTION AND USES

Total domestic consumption of ferroalloys in 1985 was lower than that of 1984 owing to weaker demand by major consuming industries. Consumption patterns for ferroalloys followed the production patterns of the steel and ferrous casting industries, its major end-use markets, which each experienced production cutbacks of slightly more than 5%. However, overall consumption of silicon metal increased moderately, mainly the result of stronger demand by the chemical industry, one of its two major markets. Although the aluminum industry, the other major consumer of silicon metal, decreased production by 15%, this did not offset the gain in silicon metal consumption by the chemical industry.

Overall demand for bulk ferroalloys of chromium, manganese, and silicon and their respective metals was down by about one-tenth in 1985 compared with that of 1984. Demand for chromium ferroalloys and metal declined by a larger percentage than that for manganese- or silicon-ferroalloys and metal.

Market conditions for ferroalloys in the United States continued to be severely depressed, mainly the result of continuing weak demand by the U.S. steel industry, its major consumer. Most major domestic steel producers continued to operate at a loss for the fourth consecutive year, and one major producer, Wheeling-Pittsburgh Steel Corp., was forced to file for bankruptcy. Along with the domestic ferroalloys industry, the U.S. steel industry continues to operate at reduced rates because of weak demand and competition from low-priced imports.

Imports of bulk ferroalloys and their respective metals represented 59% of the domestic market in 1985, up from 55% in 1984. H-C FeCr and H-C FeMn produced under the National Defense Stockpile upgrading program were included in U.S. demand calculations.

### Table 4.—U.S. consumption of ferroalloys as additives in 1985, by end use[1]

(Short tons of alloys unless otherwise specified)

| End use | FeMn | SiMn | FeSi | FeTi | FeP | FeB |
|---|---|---|---|---|---|---|
| Steel: | | | | | | |
| Carbon | 360,733 | 76,343 | [2]70,235 | 483 | 8,747 | 350 |
| Stainless and heat-resisting | [2]14,026 | 3,228 | [2]61,286 | 2,104 | 14 | 16 |
| Other alloy | [2]70,119 | [2]19,295 | [2]29,781 | 491 | 1,167 | 227 |
| Tool | 376 | ([3]) | 1,683 | ([3]) | ([3]) | -- |
| Unspecified | 753 | 660 | 28,350 | 18 | 1 | -- |
| Total | 446,007 | 99,526 | 191,335 | 3,096 | 9,929 | 593 |
| Cast irons | [4]16,318 | 2,583 | 207,741 | 23 | 2,216 | W |
| Superalloys | 326 | W | 570 | 657 | -- | W |
| Alloys (excluding alloy steels and superalloys) | 18,576 | W | 122,120 | 357 | 78 | 32 |
| Miscellaneous and unspecified | 8,820 | 2,669 | 21,882 | -- | -- | 211 |
| Total consumption | 490,047 | 104,778 | 543,648 | 4,133 | 12,223 | 836 |
| Percent of 1984 | 94 | 102 | 97 | 95 | 77 | 81 |

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

[1] FeMn, ferromanganese including spiegeleisen and manganese metal; SiMn, silicomanganese; FeSi, ferrosilicon including silicon metal, silvery pig iron, and inoculant alloys; FeTi, ferrotitanium; FeP, ferrophosphorus; FeB, ferroboron including other boron materials.

[2] Part included with "Steel: Unspecified."

[3] Included with "Steel: Unspecified."

[4] Part included with "Miscellaneous and unspecified."

### Table 5.—U.S. consumption of ferroalloys as alloying elements in 1985, by end use[1]

(Short tons of contained elements unless otherwise specified)

| End use | FeCr | FeMo | FeW | FeV | FeCb | FeNi |
|---|---|---|---|---|---|---|
| Steel: | | | | | | |
| Carbon | [2]4,573 | 69 | -- | 1,135 | 860 | -- |
| Stainless and heat-resisting | 156,277 | 314 | 37 | 35 | 468 | 15,847 |
| Other alloy | [2]24,541 | 936 | 21 | 2,327 | 1,028 | 1,235 |
| Tool | 2,416 | 209 | 134 | 522 | ([3]) | -- |
| Unspecified | ([4]) | -- | -- | W | 15 | -- |
| Total[2] | 187,807 | 1,528 | 192 | 4,019 | 2,371 | 17,082 |
| Cast irons | 3,646 | 524 | -- | 22 | -- | 356 |
| Superalloys | 8,330 | W | W | 16 | 602 | W |
| Alloys (excluding alloy steels and superalloys) | 2,238 | 149 | W | 807 | 11 | 388 |
| Miscellaneous and unspecified | 4,840 | 74 | 5 | 19 | -- | 167 |
| Total consumption | 206,861 | 2,275 | 197 | 4,883 | 2,984 | 17,993 |
| Percent of 1984 | 89 | 104 | 64 | 127 | 111 | 97 |

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

[1] FeCr, ferrochromium including other chromium ferroalloys and chromium metal; FeMo, ferromolybdenum including calcium molybdate; FeW, ferrotungsten; FeV, ferrovanadium including other vanadium-carbon-iron ferroalloys; FeCb, ferrocolumbium including nickel columbium; FeNi, ferronickel.

[2] Part included with "Miscellaneous and unspecified."

[3] Included with "Steel: Unspecified."

[4] Included with "Miscellaneous and unspecified."

### Table 6.—Stocks of ferroalloys held by producers and consumers in the United States at yearend

(Short tons)

| | Producer | | Consumer | | Total | |
|---|---|---|---|---|---|---|
| | 1984 (gross weight) | 1985 (gross weight) | 1984 (gross weight) | 1985 (gross weight) | 1984 (gross weight) | 1985 (gross weight) |
| Manganese ferroalloys[1] | 30,806 | W | 145,442 | W | 176,248 | 119,342 |
| Silicon alloys[2] | 91,110 | 120,017 | 27,261 | 25,399 | 118,371 | 145,416 |
| Ferrochromium[3] | 19,414 | 20,387 | 26,302 | 32,166 | 45,716 | 52,553 |
| Ferroboron[4] | 114 | 157 | 197 | 212 | 311 | 369 |
| Ferrophosphorus | 141,212 | 60,388 | 1,720 | 1,495 | 142,932 | 61,883 |
| Ferrotitanium | W | W | 548 | 667 | 548 | 667 |
| Total | 282,656 | 200,949 | 201,470 | 59,939 | 484,126 | 380,230 |
| | 1984 (contained element) | 1985 (contained element) | 1984 (contained element) | 1985 (contained element) | 1984 (contained element) | 1985 (contained element) |
| Ferrocolumbium[5] | W | W | W | W | 476 | 559 |
| Ferromolybdenum[6] | 1,226 | 1,257 | 361 | 298 | 1,587 | 1,555 |
| Ferronickel | W | W | 692 | 1,930 | 692 | 1,930 |
| Ferrotungsten | W | W | 41 | 40 | 41 | 40 |
| Ferrovanadium[7] | 946 | W | 334 | 360 | 1,280 | 360 |
| Total | 2,172 | 1,257 | 1,428 | 2,628 | 4,076 | 4,444 |

W Withheld to avoid disclosing company proprietary data.

[1] Includes ferromanganese, silicomanganese, and manganese metal.

[2] Includes ferrosilicon, miscellaneous silicon alloys, and silicon metal.

[3] Includes other chromium alloys and chromium metal.

[4] Consumer totals include other boron materials.

[5] Consumer totals include nickel columbium.

[6] Consumer totals include calcium molybdate.

[7] Includes other vanadium-iron-carbon ferroalloys.

## PRICES

Published prices for imported ferrochromium products showed a firming trend during the first three quarters of the year, mainly the result of steady demand by stainless steel mills. However, an apparent oversupply of ferrochromium tended to push imported prices down in the fourth quarter by 1 to 3 cents per pound of contained chromium. Continued demand by stainless steel mills and the possibility of disruption of supplies from the Republic of South Africa, the major source of chromium materials, helped to prevent prices from falling further. With the exception of U.S. vacuum melted chromium metal pellets, which increased from $4.40 per pound to $4.62 per pound on October 11, posted prices for all other domestically produced chromium products in 1985 were unchanged or not listed.

Posted prices for most other ferroalloys began to weaken by the beginning of the second quarter owing to declining demand by major consuming industries and stronger competition among producers.

The average posted price of imported bulk ferroalloys increased for most chromium products in 1985 compared with that of 1984. For example, by 4% to $0.46 per pound of chromium for charge chrome containing 60% to 65% chromium and by 1% to $0.87 per pound of chromium for low-carbon ferrochromium containing up to 0.05% carbon. However, the average posted price for most major imported manganese and silicon bulk ferroalloy products declined compared with that of 1984. For example, by 5% to $0.32 per pound of manganese for medium-carbon ferromanganese, by 11% to $0.17 per pound for silicomanganese, by 10% to $0.37 per pound of silicon for 50% ferrosilicon, by 15% to $0.35 per pound of silicon for 75% ferrosilicon, and by 4% to $0.57 per pound of silicon for silicon metal containing up to 1% iron. Average listed prices for comparable domestically produced bulk ferroalloys were significantly higher than these seven imports by 18%, 9%, 27%, 39%, 22%, 32%, and 10%, respectively.

The average posted price of many specialty ferroalloys that compete as microalloying additives in the production of high-strength, low-alloy steels was lowered in 1985. For instance, the average posted price was lowered slightly to $5.66 per pound of columbium for regular-grade ferrocolumbium, by 11% to $5.78 per pound of vanadium for domestically produced ferrovanadium, and by 14% to $3.67 per pound of molybdenum for dealer exported ferromolybdenum.

Published prices were lowered from a range of $48-$52 to $40-$42 per metric ton for chromium ore from the Republic of South Africa on May 9 and from a range of $1.44-$1.47 to $1.40-$1.45 per long ton unit (22.4 avoirdupois pounds) of manganese content for manganese ore on March 21. In contrast, the posted price for chromium ore imported from Turkey was raised from $110 to $125 per metric ton on November 7.

Although published prices for domestically produced ferroalloys were generally much higher than those of imports, discounting by domestic producers was reported throughout the industry. Prices for selected domestically produced ferroalloys are shown in the following tabulation:

| Alloy | Yearend price[1] | |
|---|---|---|
| | 1984 | 1985 |
| Charge chromium (66% to 70%) | $0.54 | $0.54 |
| Low-carbon ferrochromium, 0.02% maximum carbon (Simplex) | 1.00 | 1.00 |
| Standard 78% ferromanganese, per long ton of alloy[2] | 325.00 | 320.00 |
| Ferromolybdenum, dealer export | 3.55 | 3.26 |
| Ferronickel | 3.16 | 3.16 |
| Ferrosilicon, 50% | .45 | .40 |
| Ferrosilicon, 75% | .47 | .40 |

[1] Per pound contained, except as noted otherwise. If range of prices was quoted, the lowest price is shown.

[2] Prices for imported material. List price for domestic material suspended on June 28, 1984.

Source: Metals Week.

## FOREIGN TRADE

The trade deficit for ferroalloys declined from $470 million in 1984 to $425 million in 1985. However, a surplus of $6 million for ferroalloy metals in 1984 changed to a deficit of $40 million in 1985.

Both quantity, on a gross weight basis, and value of exported ferroalloys and ferroalloy metals declined in 1985, by 21% to 106,000 tons and 18% to $135 million, respectively. The quantity and value of exported ferroalloys and ferroalloy metals were 9% and 23% of the quantity and value of imports in 1985, respectively, compared with 11% and 26%, respectively, in 1984.

Total imports for consumption of ferroalloys and ferroalloy metals decreased 7% in quantity to 1.1 million tons and 5% in value to $600 million, compared with those of 1984. Of the imported bulk ferroalloys, the quantity of chromium ferroalloys and manganese ferroalloys declined by 23% and 3%, respectively, while that of silicon ferroalloys increased by 8%. Imports of chromium metal and manganese metal declined by 15% and 36%, respectively. However, imports of silicon metal were up by 105%. Imports declined by 15% for ferronickel and by 13% overall for all other ferroalloys. Ferroalloy and ferroalloy metal imports were equal to 72% of reported consumption in 1985, the same as in 1984.

Imports of ferroalloys and ferroalloy metals to the United States were supplied by 39 countries. The geographic sources were Africa, 41%; Europe, 28%; Western Hemisphere, 24%; Middle East, 3%; Oceania, 4%; and Asia, 1%. The four principal suppliers were the Republic of South Africa, 37%; France, 11%; Brazil, 8%; and Canada, 7%. Combined imports of chromium ferroalloys from the Republic of South Africa and Zimbabwe were 73% of total chromium ferroalloys, the same as in 1984. Of the total chromium ferroalloys, the Republic of South Africa supplied 61%. Turkey was the third leading supplier of chromium ferroalloys with 9% of the total. Major sources of imported manganese ferroalloys were the Republic of South Africa, 37%; France, 22%; Mexico, 9%; Canada, 7%; and Brazil, 6%. The principal sources of ferrosilicon imports were Brazil, 22%; Venezuela, 18%; Norway, 16%; Canada, 16%; and the U.S.S.R., 10%. The leading suppliers of ferronickel were the Dominican Republic, 54%; New Caledonia, 39%; and Colombia, 4%. The main suppliers of all other ferroalloys were Brazil, 52%; the United Kingdom, 12%; Australia, 10%; France, 9%; and Belgium, 5%. Major suppliers of ferroalloy metal imports were the United Kingdom, Japan, China, and France with 44%, 32%, 11%, and 10%, respectively, of the chromium metal; the Republic of South Africa with 98% of the manganese metal followed by Belgium with less than 2% of the total; and Brazil, Canada, Portugal, France, and the Republic of South Africa with 26%, 20%, 12%, 8%, and 8%, respectively, of the silicon metal. In 1984, the leading suppliers of silicon metal were Canada (33%), France (16%), Yugoslavia (13%), Brazil (11%), and the Republic of South Africa (8%).

## Table 7.—U.S. exports of ferroalloys and ferroalloy metals

| Alloy | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| **Ferroalloys:** |  |  |  |  |  |  |
| Ferrocerium and alloys | 41 | $372 | 29 | $304 | 28 | $314 |
| Ferrochromium and ferrochromium-silicon | 4,247 | 4,822 | 15,388 | 10,542 | 10,262 | 7,688 |
| Ferromanganese | 8,433 | 5,765 | 6,764 | 4,397 | 6,927 | 4,762 |
| Silicomanganese | 6,426 | 1,746 | 5,333 | 2,237 | 3,089 | 136 |
| Ferromolybdenum | 85 | 687 | 325 | 1,567 | 631 | 2,698 |
| Ferrophosphorus | 26,933 | 3,716 | 39,603 | 5,279 | 49,674 | 5,776 |
| Ferrosilicon | 13,338 | 10,712 | 29,364 | 21,185 | 12,970 | 12,671 |
| Ferrovanadium | 775 | 6,144 | 469 | 5,205 | 454 | 4,791 |
| Ferroalloys, n.e.c | 5,775 | 7,965 | 27,485 | 16,158 | 14,498 | 24,581 |
| Tetal ferroalloys[1] | 66,053 | 41,929 | 124,761 | 66,875 | 98,533 | 63,417 |
| **Metals:** |  |  |  |  |  |  |
| Manganese | 6,391 | 8,531 | 4,082 | 5,915 | 5,162 | 7,242 |
| Silicon | 2,767 | 47,826 | 4,420 | 88,543 | 2,120 | 61,647 |
| Chromium | 238 | 2,555 | 259 | 3,627 | 222 | 2,964 |
| Total ferroalloy metals[1] | 9,396 | 58,912 | 8,761 | 98,084 | 7,504 | 71,854 |
| Grand total | 75,449 | 100,841 | 133,522 | 164,959 | 106,037 | 135,271 |

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## Table 8.—U.S. imports for consumption of ferroalloys and ferroalloy metals

| Alloy | 1984 |  |  | 1985 |  |  |
|---|---|---|---|---|---|---|
|  | Gross weight (short tons) | Content (short tons) | Value (thousands) | Gross weight (short tons) | Content (short tons) | Value (thousands) |
| **Manganese alloys:** |  |  |  |  |  |  |
| Ferromanganese containing 1% or less carbon | 5,020 | 4,431 | $4,554 | 5,575 | 4,877 | $5,098 |
| Ferromanganese containing more than 1% to 4% carbon | 53,509 | 43,419 | 25,674 | 30,383 | 24,689 | 12,923 |
| Ferromanganese containing more than 4% carbon | 350,781 | 273,849 | 87,450 | 330,916 | 257,178 | 86,368 |
| Ferrosilicon manganese | 138,494 | [1]91,339 | 44,746 | 165,523 | [1]109,719 | 51,423 |
| Spiegeleisen | 220 | (2) | 73 | 270 | (2) | 111 |
| Total manganese alloys[3] | 548,023 | 413,039 | 162,496 | 532,667 | 396,463 | 156,922 |
| **Ferrosilicon:** |  |  |  |  |  |  |
| 8% to 30% silicon | 46 | 7 | 13 | 345 | 43 | 41 |
| 30% to 60% silicon, over 2% magnesium | 10,912 | 5,030 | 7,252 | 7,586 | 3,484 | 4,981 |
| 30% to 60% silicon, n.e.c | 31,607 | 15,668 | 12,879 | 41,887 | 20,788 | 14,590 |
| 60% to 80% silicon, over 3% calcium | 6,798 | 4,300 | 6,206 | 8,554 | 5,340 | 7,714 |
| 60% to 80% silicon, n.e.c | 93,125 | 70,005 | 45,829 | 96,154 | 72,228 | 46,222 |
| 80% to 90% silicon | 1,063 | 923 | 619 | 875 | 754 | 460 |
| Over 90% silicon | 100 | 94 | 76 | 20 | 19 | 11 |
| Total ferrosilicon | 143,651 | 96,027 | 72,874 | 155,421 | 102,656 | 74,019 |
| **Chromium alloys:** |  |  |  |  |  |  |
| Ferrochromium containing 3% or more carbon | 400,676 | 225,488 | 160,054 | 304,829 | 171,587 | 131,570 |
| Ferrochromium containing less than 3% carbon | 25,132 | 17,236 | 23,397 | 26,236 | 17,525 | 24,976 |
| Ferrosilicon-chromium | 7,942 | 3,032 | 3,736 | 3,940 | 1,493 | 2,085 |
| Total chromium alloys | 433,750 | 245,756 | 187,187 | 335,005 | 190,605 | 158,631 |
| Ferronickel | 43,048 | 15,847 | 68,429 | 36,529 | 12,742 | 60,253 |
| **Other ferroalloys:** |  |  |  |  |  |  |
| Ferrocerium and other cerium alloys | 152 | (2) | 1,651 | 125 | (2) | 1,302 |
| Ferromolybdenum | 1,043 | 772 | 4,438 | 712 | 478 | 3,721 |
| Ferrotitanium and ferrosilicon-titanium | 579 | (2) | 861 | 483 | (2) | 982 |
| Ferrotungsten and ferrosilicon-tungsten | 393 | 315 | 3,420 | 130 | 103 | 951 |

See footnotes at end of table.

### Table 8.—U.S. imports for consumption of ferroalloys and ferroalloy metals —Continued

| Alloy | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Gross weight (short tons) | Content (short tons) | Value (thousands) | Gross weight (short tons) | Content (short tons) | Value (thousands) |
| **Other ferroalloys —Continued** | | | | | | |
| Ferrovanadium | 1,450 | 1,170 | $11,839 | 966 | 778 | $7,757 |
| Ferrozirconium | 759 | ([2]) | 932 | 629 | ([2]) | 729 |
| Ferroalloys, n.e.c.[4] | 3,949 | ([2]) | 22,876 | 4,197 | ([2]) | 24,179 |
| Total other ferroalloys[3] | 8,325 | XX | 46,017 | 7,241 | XX | 39,620 |
| Total ferroalloys[3] | 1,176,797 | XX | [r]537,004 | 1,066,863 | XX | 488,445 |
| **Metals:** | | | | | | |
| Manganese | 13,314 | ([2]) | 12,978 | 8,570 | ([2]) | 9,054 |
| Silicon (96% to 99% silicon) | 6,753 | ([2]) | 7,113 | 9,354 | ([2]) | 9,684 |
| Silicon (99% to 99.7% silicon) | 17,588 | 17,408 | 19,361 | 41,563 | 41,128 | 42,954 |
| Silicon (over 99.7% silicon)[5] | 880 | ([2]) | 28,907 | 885 | ([2]) | 30,729 |
| Chromium | 4,677 | ([2]) | 24,073 | 3,954 | ([2]) | 19,615 |
| Total ferroalloy metals[3] | [r]43,211 | XX | [r]92,433 | 64,326 | XX | 112,036 |
| Grand total[3] | [r]1,220,009 | XX | [r]629,436 | 1,131,189 | XX | 600,481 |

[r] Revised. XX Not applicable.
[1] Manganese content only.
[2] Not recorded.
[3] Data may not add to totals shown because of independent rounding.
[4] Principally ferrocolumbium.
[5] This category not previously included.

Source: Bureau of the Census.

## WORLD REVIEW

World demand for ferroalloys rose slightly compared with that of 1984. Overcapacity and oversupply has plagued the world ferroalloy industry in recent years, a situation that is expected to continue for the foreseeable future. Some of the restructuring required to bring production in line with demand has already taken place in the United States and Japan. However, Brazil announced plans to triple its ferroalloy capacity by 1990, mainly for silicon metal and silicon alloys. Brazil's major cost advantage is its large hydroelectric energy reserves. Reacting to Brazilian competition, the Norwegian industry underwent a reorganization that reduced the number of active producer groups from four to two. Efforts were being made to reduce costs and ensure a substantial share of the world market.

The EEC expanded its membership from 10 to 12 countries by incorporating Spain and Portugal. EEC membership for the two countries was to take effect on January 1, 1986. The EEC's Executive Commission announced in June 1985 that it had decided against allowing the official formation of Euromang, a cartel made up of EEC ferromanganese producers. Euromang failed to submit a plan to permanently reduce ferromanganese capacity by 30%, a requirement for EEC approval. At midyear, the Commission issued "General Objectives Steel 1990," a working document that projected declines in manganese consumption in both ironmaking and steelmaking. The EEC doubled quotas for duty-free imports of ferrochromium into member countries in 1985. The EEC also set quotas for this material for 1986. EEC ferrosilicon producers met with Commission officials to discuss the low level of prices set in 1983 for ferrosilicon delivered to the EEC border. As a result, the Commission began to monitor the ferrosilicon market and asked producers from countries accused of dumping in 1983 to provide details of all transactions in the Common Market since April 1985. A decision to implement a price increase was to be made after comments from non-EEC producing countries were received. Resistance to an EEC price increase could lead to Community antidumping legislation. The EEC Council of Ministers agreed to maintain the duty-free quota for imports of ferrosilicon for 1986 at about 14,000 tons, of which the Federal Republic of Germany would be the chief beneficiary. A plan to support research on ways to make its mining and materials industries more competitive was approved by the EEC's Commission.

France, the United Kingdom, and the United States reduced, or planned to reduce, the amount of material held in their respective stockpiles. However, Japan planned to increase the amount of material held in its stockpile, while the Republic of Korea announced plans to initiate a stockpiling program.

It was reported in Metal Bulletin that the Republic of South Africa's Government was considering withholding exports of chromium in retaliation for tougher U.S. sanctions. Greece planned to enter the North American ferrochromium market. The Government of Norway announced it will require licenses for companies to import goods such as manganese ore from the Republic of South Africa.

Despite initial improvements in their balance of payments, the main debtor countries have failed so far to secure a viable long-term economic future.

**Albania.**—Albania is the world's third-ranked producer of chromite. Albanian chromite ore is massive, hard, and of good quality. The average chromium oxide content is 43%, and the ratio of chromium to iron is 3 to 1. Albania reportedly signed a trade agreement with Czechoslovakia in late 1985. Albanian exports will include chrome and nickel ore in return for Czechoslovak steel products, vehicles, and machinery. In midyear, Albania raised the possibility of sending some of its large nickeliferous iron ore reserve deposits to the Province of Kosovo in Yugoslavia for ferronickel smelting. However, political considerations may preclude such an arrangement.[4]

**Australia.**—French metals producer Pechiney and the Australian group Pioneer Concrete Ltd. agreed to form a joint venture to construct a silicon metal plant near Hobart, Tasmania. The joint venture intends initially to build a single 18.5-megawatt (MW) submerged arc furnace, which will produce about 13,000 tons per year of alloy or chemical-grade silicon metal, based on technology of Pechiney's subsidiary Pechiney Electrométallurgie. The new facility, estimated to cost $34 million, will be 60% owned by Pioneer.

**Belgium.**—Production facilities for manganese ferroalloys and chemicals were included when Société Générale de Belgique SA consolidated its main chemical subsidiaries into Gechem in the final months of the year. In the restructuring, Société Européene des Dérivés du Manganése (Sedema) was absorbed from Société Carbochimique SA (CARBOCHIM) into Société d'Applications de la Chimie, de l'Electricité et des Métaux SA (SADACEM). Principal ownership of SADACEM was divided between CARBOCHIM, 65%, and Gechem, 26%. Gechem owned 99% of CARBOCHIM. Placed within a Gechem business sector were the SADACEM chemical plant at Tertre and Chemetals in the United States, both of which had been owned by Sedema, and the manganese ferroalloy plant of Belgische Vennootschap voor Mangaanproduktie SA (BELGOMANG) at Langerbrugge. Ownership of BELGOMANG was shared equally between SADACEM and a state-owned company.

SADACEM and Sedema, member companies in Société Générale de Belgique, combined forces to buy Gulf Chemical & Metallurgical Corp.'s Freeport, TX, plant from the Lissauer Group. SADACEM, a ferroalloy producer, and Sedema will operate the plant as equal partners. The facility will be used to recover molybdenum and vanadium from spent catalysts used in the petroleum refining industry.[5]

**Brazil.**—Brazil announced plans to triple its output of ferrosilicon and silicon metal by 1990, from the current level of about 190,000 tons to about 590,000 tons. Brazil has abundant supplies of raw materials, low-cost electric energy, and cheap labor, all of which would be expected to make Brazil a major supplier of silicon materials to the world market.

Cia. de Ferro-Ligas da Bahia S.A. (FERBASA) installed the first of three 13,000-ton-per-year furnaces at its new 75% ferrosilicon plant in Salvador. The plant will have a capacity of about 39,000 tons per year. The facility has a 10-year contract to export about 24,000 tons per year to Marubeni Corp., Japan. Eletrometalur S.A. Indústria e Comércio and Ila og Lilleby Smelteverker A/S of Norway formed a joint venture to produce silicon metal in Brazil. Two 14,000-kilowatt furnaces will be built at Captain Eneas in Minas Gerais State. The plant is expected to produce about 20,000 tons per year of high-quality silicon metal, all of which will be exported. Minerações Brasileiras Reunidas S.A.'s (MBR) ferrosilicon project was approved by Conselho de Nao-Ferrosos e de Siderúrgia S.A. MBR planned to build two 15,000-kilovolt-ampere (kV•A) furnaces in the Pirapora industrial complex. The first unit was scheduled for completion in 1987. Eletrovale, a joint venture 60% owned by Cia. Vale do Rio Doce (CVRD) and Eletrometalur, and 20% each by Mitsubishi Corp. and Kawasaki Steel Corp., began construction of its 27,000-ton-per-year ferrosilicon plant at Nova Era in Minas Gerais State. The plant was scheduled to go on-stream in late 1986.

Italmagnésio S.A. Indústria e Comércio planned to begin silicon metal production by March 1986 by converting its new 24-megavolt-ampere (MV•A) submerged arc ferrosilicon furnace to silicon metal production. The new furnace was scheduled to be put on-line in January 1986. Furnace output was expected to be 1,100 tons of silicon metal per month. Italmagnésio also planned to build a 13-MV•A furnace for silicon metal production. The furnace was expected to be completed by June 1986. Cia. Brasileira Carbueto de Calcio S.A. (CBCC) converted an old 30-MV•A ferrosilicon furnace to silicon metal production. CBCC also brought a new 30-MV•A furnace on-stream about midyear for ferrosilicon production. The new unit's production capacity was rated at about 20,000 tons per year. Ferro-Ligas Assofun S.A. began installation of an electric furnace for ferrosilicon production at its ferroalloy facility in São Joas da Boa Vista, which would double its capacity to about 15,000 tons per year. The company began negotiations with Nippon Kokan K.K. and Mitsui Co. Ltd. in an effort to establish a joint venture to raise part of the financing needed for construction.

Alcan Alumínio do Brasil S.A. sold its ferroalloys division to Cia. Paulista de Ferro-Ligas. Alcan's properties included two single-furnace facilities with a total capacity of about 19,000 tons per year of 75% ferrosilicon. Alcan produces silicomanganese at a third plant. All of the plants are in Minas Gerais. Brazil's Interior Minister approved new investment in the Inoculantes e Ferro-Ligas Nipo Brasileiros S.A. (INONIBRAS) ferrosilicon project. INONIBRAS planned to increase capacity to 29,000 tons per year from 7,000 tons. Osaka Special Alloy Ltd., Japan, holds a 30% share in the company, whose smelter is in Mato Grosso State. Cia. de Ferro-Ligas Minas Gerais S.A. put a 15-MV•A furnace online in August, increasing its ferrosilicon capacity from 26,000 tons per year to 40,000 tons of the 75% silicon alloy.

Metalman Indústria e Comércio Manganese Electrolitico, a subsidiary of Metalur Administração Participações Ltda., planned to install a $40 million plant at Rosario near São Paulo. The plant will produce electrolytic manganese metal and electrolytic manganese dioxide, among others. CVRD will provide the 80,000 tons per year of manganese ore required for the calcination and reduction process from its mineral deposit in Carajás. The plant's first phase was scheduled for completion in late 1987.

Both Paulista de Ferro-Ligas and Prometal-Produtos Metallúrgicos S.A. announced plans to build plants to convert Carajás manganese ore to ferromanganese and silicomanganese. Each plant would have a rated capacity of about 40,000 tons per year and be situated in the region. Production was planned to start in the 1986-88 period. Pilot plant trials demonstrated the feasibility of producing standard ferromanganese and silicomanganese with feed material from the Azul deposit using charcoal as a reductant.

Urucum Mineração S.A., operator of Brazil's largest manganese ore deposit, had projected 1985 ore production at 55,000 tons. The company may construct a ferroalloys plant near the mine.

FERBASA announced that it expected to reach an installed capacity of about 165,000 tons for all chrome alloys in 1985. The company exported nearly 50% of its major product, H-C FeCr, in 1984.

Construction began in Brazil on a new $1.7 million plant capable of producing about 200 tons per year of ferrotungsten and about 200 tons per year of tungsten carbide powders. The plant was expected to be completed in early 1987 and will use scheelite ores mined at Currais Novos, Rio Grande do Norte. Plant ownership will be divided among Tenenge Tecnica Nacional de Engenharia S.A. with 60%, Tomaz Salustino, 35%, and the Rio Grande do Norte State Government, 5%.

Cia. Brasileira de Metalúrgia e Mineração (CBMM) announced that it will begin producing columbium metal for export in 1987. CBMM planned to build an electron beam furnace at its ferrocolumbium plant in Araxá. Plant production is expected to be about 100 tons per year of metal, which will go to the superconductor industry. CBMM already is the world's largest producer of ferrocolumbium and columbium oxide.[6]

**Canada.**—In the first half of the year, Elkem Metals Canada came under full ownership of Elkem of Norway. Elkem Metals

Canada owns plants at Beauharnois and Chicoutimi, Quebec. Products include silicon metal, ferrosilicon and manganese ferroalloys.

Renzy Mines began construction of a new $4 million plant near Edmonton, Alberta, for recovery of vanadium pentoxide and other nonferrous oxides from fly ash by 1986. The fly ash will come from tar sands that Suncoroil will provide under a profit-sharing agreement. Suncoroil's Fort MacMurray oil sands refinery will supply up to about 34,000 tons per year of fly ash until stocks run out. Production of ferrovanadium would likely be undertaken if market conditions were right.[7]

**Chile.**—A strike by unionized workers in May halted ferromolybdenum (FeMo) and molybdic oxide ($MoO_3$) production for about 2 weeks at Molíbdenos y Metales S.A.'s (Molymet) plant in San Bernardo. Molymet, a major world producer of molybdenum (Mo) products, has an annual capacity of about 5 million pounds of contained Mo as FeMo and 22 million pounds of contained Mo as $MoO_3$. The company refused to take delivery of concentrates for conversion during the strike.

**China.**—China, a net importer of many ferroalloys since 1982, resumed exports of a wide range of ferroalloys in 1985. Exports in considerable quantities of ferrochromium, ferromanganese, and ferrosilicon were resumed, with lesser quantities of ferromolybdenum, ferrotitanium, ferrotungsten, ferrovanadium, and silicomanganese. China also began to further develop its more than 1-million-ton-per-year ferroalloy production capacity to coordinate with the Boashan steel complex, which has recently come onstream.

China, which had already agreed to buy 55,000 tons of chrome ore from Etibank, Turkey, purchased an additional 11,000 tons of Turkish ore from private sector interests.

China also planned to expand domestic production of ferrosilicon by building a 40,000-ton-per-year ferrosilicon plant in Gansu Province. The facility is due onstream in mid-1987. The China National Machinery and Equipment Import and Export Corp. of Beijing contracted with Mannesmann Demag Hüttentechnik AG of the Federal Republic of Germany for the engineering, planning, and supply of the plant. Two Demag 25-MV•A submerged arc furnaces will be supplied. A Chinese silicon metal producer redesigned two furnaces in the Jinshan plant in Jingzhou to meet the growing demand for silicon metal. China's exports of silicon metal to Japan in 1985 increased dramatically, compared with those of 1984.[8]

**Colombia.**—Cerro Matoso S.A. restarted its ferronickel plant in December and was operating at 66% of capacity. The furnace had been shut down for repairs in January and in August. Continued heavy financial losses and repeated technical difficulties make the future of the project uncertain. Plant production of contained nickel was estimated at 25 million pounds.

**Dominican Republic.**—Falconbridge Dominicana C por A announced in October that it planned to shut down for a 5-week period beginning December 20. The shutdown will prevent excessive accumulation of the company's stocks but may have come too late in the year to stop the price erosion in the market. Falconbridge had previously shut down for 1 week in August.

**Finland.**—Outokumpu Oy started up its new ferrochromium plant at Tornio. The company's expected production was about 140,000 tons of charge chrome in 1985, and 175,000 to 200,000 tons in 1986. Although Finland is a significant charge chrome producer, its production is very small compared with that of the Republic of South Africa. With respect to consumption by the Finnish stainless steel industry and assuming 90% recovery in the process, 140,000 tons of ferrochromium (52% chromium) would be approximately equivalent to 410,000 tons of stainless steel, based on a chromium content of about 16%.[9]

**France.**—Pechiney Electrométallurgie and Bozel Electrométallurgie, part of the electrometallurgy department of Pechiney, have an installed power capacity of 420 MW. Silicon metal and silicon alloys account for about 50% of this capacity. The two companies are leading world producers of silicon for silicon applications. About 40% of the silicon metal produced goes to the light metal castings market. The two Pechiney subsidiaries also produce a wide range of ferrosilicon for the steel industry and the foundry sector. Standard-grade ferrosilicon is made mainly in plants at Dunkirk and Laudun. High-purity material is produced at the Bellegarde facility. Silicon metal is produced mainly at the Montricher, Anglefort, Les Clavaux, Rioupéroux, and Château-Feuillet plants in France. In December, Pechiney announced that the Anglefort plant will be progressively targeted to produce silicon metal. One of Anglefort's ferrosilicon furnaces was being converted to silicon metal production and was expected to come on-stream early in 1986.[10]

Late in 1985, International Alloys & Metals was formed by two Pechiney subsidiaries, Pechiney World Trade and Pechiney Electrométallurgie, to market ferroalloys. Three key consumer markets for the company are the EEC countries, Japan, and the United States.

The Government of France began selling various materials including charge ferrochrome contained in its strategic stockpile.

**Greece.**—HFA, a subsidiary of the state-controlled Helenic Industrial Mining & Investment Co., announced that it planned to double the capacity of its integrated ferrochromium smelter to about 110,000 tons per year at its Tsingeli plant in central Greece by late 1986. The expansion of smelting capacity would be achieved by replacing the plant's 20-MV•A furnace with a 36-MV•A unit. After the expansion of capacity has been completed, HFA plans to export between 27,000 and 33,000 tons of ferrochromium to the United States and Canada, 44,000 to 55,000 tons to Europe, and 22,000 to 27,000 tons to Japan. Currently, almost all of HFA's ferrochromium production is sold in the European market. Bomar Resources Inc. was named as the exclusive U.S. representative for HFA.

In March, operations resumed at Larco S.A.'s Larymna ferronickel smelter in Beotia after a 2-week strike and a furnace explosion in February. The smelter also reportedly operated at about 50% of capacity in 1984 and produced about 15,000 tons of contained nickel.[11]

**Iceland.**—Icelandic Alloys Ltd.'s production of ferrosilicon dropped below 1984 levels, owing to a 7-week shutdown of one of its 35,000-kV•A electric furnaces. The plant operated at full capacity in 1984. Financial restructuring of the company to reduce long-term debt has been completed. Icelandic Alloys also obtained long-term sales guarantees from Elkem, Norway, and Sumitomo Corp., Japan, which will provide more effective plant utilization in years of poor demand for ferrosilicon. Construction of the 25,000-ton-per-year silicon metal plant at Reydarsjordur has been delayed until 1986.

**India.**—Orissa Mining Corp. Ltd. (OMC) began production at its new 55,000-ton-per-year ferrochromium plant in Bamnipal, Keonjhar District, Orissa State. Power shortages delayed commissioning operations. Initial output was expected to go to Japan. The plant incorporates a number of technical innovations that were expected to reduce the cost of producing ferrochromium by 25%, compared with that of conventional plants. OMC also filed an official application for the construction of a second ferrochromium plant in Orissa. However, the Indian Government linked the construction of a coal-fired powerplant as a condition for the construction of a second plant. OMC will be expected to finance the powerplant, thereby incurring a large debt burden on the second ferrochromium plant. Most of Orissa's power currently comes from hydroelectric plants that are susceptible to power cuts during the drought season.

Indian Charge Chrome Ltd. (ICC), a subsidiary of Indian Metals and Ferro Alloys Ltd. (IMFA), signed a $100 million contract with a Swedish consortium to build a coal-fired powerplant to supply electrical power to ICC's new 50,000-ton-per-year charge chrome plant at Choudar in Orissa and its 45,000-ton-per-year plant at Therubali. Ferroalloys producers have experienced severe electrical power shortages in Orissa owing to severe droughts that affected hydroelectric supplies. The new powerplant should permit the plants to operate at capacity. Output of both plants is for export.

Ipicol and Aryan Mining and Trading Corp. planned to build a 2,700-ton-per-year electrolytic manganese plant in Orissa State, pending approval by the Government of India. Technical assistance for building the plant will be supplied by Sumitomo Metal Industries Ltd. and Chuo Denko K.K. of Japan.

Ispat Alloys Ltd. in Balasore, Orissa, was issued a letter of intent by the Government to produce about 2,700 tons per year of silicon metal. IMFA is the only current producer of silicon metal, with a capacity of about 5,500 tons per year. Ispat's capacity is small compared with those of other units in the world, which are designed to produce about 8,000 to 26,000 tons of silicon metal per year. The metal is needed as an additive in aluminum alloys and as raw material in the semiconductor industry.[12]

**Italy.**—Industria Elettrica S.p.A. (Indel) began installation of additional silicon metal capacity at its Ospitale di Cadore facility. A new 24-MV•A furnace is being added to the existing 10-MV•A and 24-MV•A furnaces. The expansion will raise Indel's capacity to about 31,000 tons per year from a current level of about 19,000 tons. All of the new output is slated for export. Indel also produces about 22,000 tons per year of 75% ferrosilicon at its Domodossola plant. The company is also studying the possible production of ferrochromium and other alloys.

Elkem of Norway acquired a 20% share in Officine Elettrochimiche Trentine S.p.A. (OET), a ferroalloys producer in northern Italy. Elkem also undertook to market all of OET's products outside Italy. OET makes various specialized, highly refined alloys such as magnesium ferrosilicon, high-purity ferrosilicon, and calcium silicon. The company reportedly is Western Europe's largest producer of ferrotitanium.[13]

**Japan.**—Japan's Ministry of International Trade and Industry (MITI) plans to offer domestic ferrochrome, ferronickel, and ferrosilicon producers financial support in exchange for scrapping or mothballing plant capacity by March 31, 1987. MITI promised producers who comply with the Law of Extraordinary Measures for Depressed Industries that they will be exempt from having to pay any or most of their fixed property taxes. Most ferrosilicon producers were expected to accept the offer by March 31, 1985, while ferrochrome and ferronickel producers were expected to conform to the plan by March 31, 1986. MITI indicated these measures were necessary to offset major inroads by foreign ferroalloys producers whose power costs are much below those of Japanese producers. Under the plan, domestic ferrochrome capacity would be cut 10% from the current 573,000-ton-per-year operating level, while ferronickel operating capacity would be cut 12% from the present 420,000-ton-per-year level. Ferrosilicon capacity was expected to be reduced by about 55,000 tons per year to 295,000 tons per year. Eight ferrochrome producers, five ferrosilicon producers, and four ferronickel producers agreed to cut their plant capacities in conformance with the Government's recommendations. In March, MITI's Industrial Structure accepted proposals by the country's ferrochromium and ferronickel producers for Government assistance. H-C FeCr production capacity would be cut by 10% and ferronickel production capacity would be cut 12% over a period ending June 30, 1988. However, the proposed restructuring will not affect ferrochromium supply unless active operating capacity is reduced.

Japan's Metal Mining Agency received $17.6 million to increase the size of its national and semigovernmental ferroalloy stockpiles by 2 days of consumption during the fiscal year that began March 1, 1985. The stockpiles now jointly contain 16 days of consumption of ferrochrome, manganese, molybdenum, nickel, tungsten, and vanadium. MITI also submitted a budget request to the Ministry of Finance in August to increase both stockpiles by an additional 2 days of consumption. This expansion, to begin March 31, 1986, would raise the stockpiles to 20 days of consumption.

Japan planned to reduce duties on nine ferroalloys by April 1, 1986, according to MITI. Ferromolybdenum would be cut, on an ad valorem basis, by 20% to 3.92%; ferrocolumbium, ferrosilicon, ferrovanadium, and silicomanganese by 20% to 3%; ferrochromium by 10% to 7.2%; ferromanganese by 20% to 7.68%; and ferrotungsten by 20% to 4.9%. Later, the Japanese Finance Ministry indicated that implementation of the tariff roductions would be moved up to January 1 in an effort to calm U.S. sentiment against alleged unfair trade practices by Japan.

Total production of ferroalloys decreased slightly compared with that of 1984. Ferrochromium, ferromanganese, silicomanganese, and ferrosilicon production amounted to about 385,000 tons, 487,000 tons, 239,000 tons, and 166,000 tons, respectively. Production of manganese ferroalloys overall declined by about 9%, that of ferrosilicon by about 2%, while ferrochromium increased by about 8%.

At midyear, Mizushima Gokintetsu Ltd. began production of H-C FeMn in a shaft furnace situated within a steelmaking complex of parent company Kawasaki Steel. Demand for manganese ferroalloys continued to be diminished through hot metal pretreatment practices by steelmakers, especially at Nippon Steel Corp.[14]

**Korea, Republic of.**—The Republic of Korea announced plans to begin stockpiling ferrochromium and molybdenum. This action was taken to ensure adequate supplies of raw meterials for the country's stainless steel industry. The Korean Office of Supply expected the stockpile to hold about 1,300 tons of ferrochromium and about 200 tons of molybdenum by yearend 1985.[15]

**New Caledonia.**—Société Métallurgique le Nickel (SLN) planned to restructure its operations in New Caledonia into a separate wholly owned subsidiary. The subsidiary will operate SLN's New Caledonia Mines and the Doniambo smelter. It will also be responsible for ore exports. SLN's Thio and Kouaoua mining operations have been subjected to destructive attacks by separatists with consequent interruption of ore deliveries to the Doniambo smelter. However, SLN arranged to buy ore from some of New Caledonia's six independent mines in case of further disruptions to its own mining operations. SLN produces ferronickel, nickel concentrates, and nickel metal. The smelter's expected production in 1985 was about 50,000 tons of contained nickel. Toward yearend 1986, SLN lowered its projected output for the Doniambo smelter to about 48,000 tons of contained nickel.[16]

**Norway.**—In December, Elkem announced plans to buy Orkla Industrier A/S's 50% share in Orkla Metal A/S's ferrosilicon plant in Thamshavn and its 51% share holding in Bjoelvefossen A/S. Elkem also began negotiating with a third Norwegian ferroalloy producer, Tinfos Jernverk A/S, with the aim to establish a close working agreement in the areas of technology and marketing. With this consolidation of the Norwegian ferrosilicon industry, Elkem would effectively control about 386,000 tons per year of Norwegian ferroalloy capacity and about 110,000 tons per year of U.S. production through its U.S. subsidiary Elkem Metals. Additionally, Elkem holds a 30% interest in and an exclusive marketing agreement with Icelandic Alloys.

In October, Norway's Finance Minister proposed an increase in the electricity tax to be applied to all consumers at a uniform rate, from a current 0.37 to 0.39 cent per kW•h, effective in 1986. Norwegian ferrosilicon producers had sought some reduction in the electricity tax because of the depressed state of the ferrosilicon market.

Hafslund A/S began construction of an 11,000-ton-per-year metal powder plant at its Sarpsborg ferrosilicon facility. The plant, scheduled to come on-line early in 1986, will produce high-quality metal powders by water atomization. Products will include fine-grained 15% ferrosilicon for heavy media separation of ores and scrap.[17]

Elkem became 100% owner of Elkem Metals, United States, and Elkem Metals Canada. Elkem also acquired a 20% share in OET of Italy, a ferroalloys producer. Additionally, Elkem undertook to market all of OET's products outside Italy. OET makes various specialized, highly refined alloys such as magnesium ferrosilicon, high-purity ferrosilicon, and calcium silicon, among others. Orkla Industrier acquired a 51% interest in Bjoelvefossen, a ferrosilicon producer. Tinfos Jernverk planned to convert its two 12,000-kV•A ferrosilicon furnaces to silicon metal production, one by July 1985 and the other by February 1986.

Loss of ferrosilicon production owing to furnace breakdowns was experienced by Finnfjord Smelteverk A/S, Orkla Metal, and Hafslund early in 1985. Loss of silicon metal production was reported by Elkem, owing to a furnace breakdown in October at its Fiskaa works.

**South Africa, Republic of.**—The Republic of South Africa is the world's largest producer and exporter of both chrome ore and ferrochrome. The country's mines and smelters reportedly operated near capacity. The Republic of South Africa is also a major supplier of electrolytic manganese metal, ferromanganese, and manganese ore, among others. High inflation and rising energy costs were expected to cause problems for ferroalloy producers in 1985. In April, the Government of Norway announced that the country's companies would require licenses to import goods from the Republic of South Africa. Norwegian ferroalloy producers expressed concern that this action might lead to a limit or ban on shipment of manganese ore from the Republic of South Africa on which their production of ferromanganese and silicomanganese depends.

Gencor took over operating responsibility for the 132,000-ton-per-year Tubatse charge chrome plant at Steelport from Union Carbide on April 1. Gencor holds a 51% interest in Tubatse, and Union Carbide holds the remaining 49%. Union Carbide continued to market all of Tubatse's ferrochrome output. The Tubatse plant is among the five largest ferrochrome producers in the Republic of South Africa.

Emcor and Deltamang, the world's two largest producers of electrolytic manganese metal, merged their operations to form a new company, Manganese Metal Co. Pty. Ltd. (MMC). Emcor owns a 51% share of the new company. Emcor's plant is near Johannesburg, while Deltamang's facility is in the eastern Transvaal. Construction of a 22,000-ton-per-year electrolytic manganese plant by Brazil's Eletrometalur was expected to put extreme pressure on South African producers to maintain their market share. However, the Republic of South Africa has an abundant supply of manganese raw materials from domestic sources, reliable and competitive energy supplies, and a good labor supply, all of which makes it likely that its manganese industry will remain a key supplier for some years.

Silicon Smelters Ltd., a susidiary of South African Manganese Amcor Ltd., announced plans to expand their silicon metal production capacity by about 26,000 tons per year over a 4-year period. A fourth furnace at Silicon Smelters' Witkop plant was scheduled to come on-line in 1987 with a fifth furnace to follow 2 years later.[18]

**Spain.**—Sociedad Española de Carburos Metálicos S.A. reportedly planned to invest about $19 million in the construction of a hydroelectric power installation at Santa Eugenia in Galicia. This action is part of an attempt by the company to improve power consumption efficiency.

Ferroaleaciones Españolas S.A. (FESA) requested the same power rate reduction from Spain's Ministry of Industry that was granted to five other domestic ferroalloys producers during the past 2 years. FESA also maintained that it was eligible for lower rates since the price of ferrochrome, the company's main product, was depressed. FESA operates a plant at Medino del Campo, of which certain operations could be shut down without the lower power rate granted other ferroalloys producers.[19]

**Sweden.**—Uddevalla Kiselmetalverk AB, a joint venture formed by HB-Consult and Skanska Cement, planned to build a 33,000-ton-per-year silicon metal plant in Uddevalla. The plant was scheduled to come onstream in early 1988. The facility's overall production costs were expected to be low since waste heat from the furnaces will be purchased by the Uddevalla's district heating system.

Malmo Industrikombinat AB, also jointly owned by Skanska Cement and HB-Consult, planned to build a 55,000-ton-per-year ferrosilicon plant at Swede Harbour, Malmo. Construction was scheduled to begin in April 1986, with startup of the plant planned for 1988. Power costs for the facility will be partially offset by the sale of waste heat from the furnaces to the Malmo municipality.[20]

**Turkey.**—Bilfer Madencilik AS reportedly planned to reactivate several idled chrome ore mines. This action was in response to improved market conditions. The company's production goal in 1985 was about 80,000 tons of salable metallurgical-grade chrome ore, about three times that produced in 1984. An estimated 28,000 tons of material had been sold by November to China, the Republic of South Africa, and the United States.

Egemetal Madencilik A/S signed an agreement with Bomar Resources, United States, and Etibank, the Turkish state mining agency for possible development of chromite ore reserves in the Orhanel region. Initial work on the project will be limited to data collection and research and development. The agreement calls for establishment of a new company owned 40% each by Etibank and Egemetal, and 20% by Bomar Resources, allowing the company to qualify for Government incentives granted to foreign capital investment.[21]

**U.S.S.R.**—CBMM, Brazil, announced in May that the U.S.S.R. purchased 220 tons of the company's high-purity columbium oxide, amounting to about one-third of CBMM's current annual production capacity. The material was scheduled for delivery in 1985. The U.S.S.R. was also expected to buy about 600 tons of standard-grade ferrocolumbium from CBMM.

**United Kingdom.**—Brandeis Intsel Co. Ltd. completed the sale of about 25% of the United Kingdom's stockpile of strategic metals. The materials sold included about 26,000 tons of H-C FeMn, 29,000 tons of manganese ore fines, 1,400 tons of battery-grade manganese ore, 105 tons of ferrovanadium, and 100 tons of cobalt. Total market value of the materials sold was estimated at $13 million. The stockpile reportedly also contains ferrochromium, chromium ore, and vanadium pentoxide. The Government announced in November 1984 that it planned to sell its stockpile, less than 2 years after it had started to build it.

**Venezuela.**—C.V.G. Ferrosilicio de Venezuela C.A. (FESILVEN) shipped about 60,000 tons of ferrosilicon, compared with about 40,000 tons in 1984. Production increased to about 56,000 tons from 40,000 tons for the same period, taking the company close to its current rated capacity of 60,000 tons. The company planned to replace imported coal from Colombia and coke from France and the United Kingdom with domestically produced material. FESILVEN also began drawing up plans to use locally available charcoal.

**Yugoslavia.**—Feronikl's (FENI) ferronickel complex in Kavadarci, Macedonia, was permanently closed in 1985, and buyers for the plant and equipment were being sought. The plant, which was idled in 1984, was completed in 1982. FENI had planned to export from 80% to 90% of its production. According to Government analyses, the plant could not operate economically for the next 10 to 15 years because of low-grade ores and low nickel prices.

## Table 9.—Ferroalloys: World production, by country, furnace type, and alloy type[1]

(Thousand short tons)

| Country, furnace type,[2] and alloy type[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Albania: Electric furnace, ferrochromium[e] | 31 | 33 | 39 | 44 | 47 |
| Argentina: Electric furnace: | | | | | |
| Ferromanganese | 25 | 27 | 28 | 26 | 24 |
| Silicomanganese | 14 | 17 | 15 | 15 | 18 |
| Ferrosilicon | 11 | 19 | 17 | 22 | 15 |
| Other | [r]2 | 5 | (4) | 4 | 5 |
| Total[5] | [r]52 | 67 | 60 | 67 | 62 |
| Australia: Electric furnace:[e] | | | | | |
| Ferromanganese | 74 | 60 | 59 | 84 | [7]76 |
| Silicomanganese | [r]33 | 33 | 22 | 34 | [7]30 |
| Ferrosilicon | 20 | 22 | 21 | 17 | 20 |
| Total[5] | 127 | 115 | 101 | 135 | 126 |
| Austria: Electric furnace, undistributed | 13 | 15 | 15 | 14 | 15 |
| Belgium: Electric furnace, ferromanganese[e] | 99 | 99 | 99 | 105 | 99 |
| Brazil: Electric furnace: | | | | | |
| Ferromanganese | 119 | [r]135 | 114 | 117 | [7]149 |
| Silicomanganese | 157 | [r]179 | 197 | 205 | [7]199 |
| Ferrosilicon | [r]162 | [r]157 | 198 | 216 | [7]248 |
| Silicon metal | 21 | 20 | 23 | 30 | [7]32 |
| Ferrochromium | 131 | 107 | 85 | 138 | [7]140 |
| Ferrochromium-silicon | 10 | 3 | 6 | 8 | [7]10 |
| Ferronickel | [r]3 | [r]4 | 9 | 10 | [7]10 |
| Other | [r]18 | [r]16 | 14 | 23 | [7]26 |
| Total | [r]621 | [r]621 | 641 | 747 | [7]814 |
| Bulgaria: Electric furnace: | | | | | |
| Ferromanganese[e] [8] | 37 | 37 | [r]33 | [r]24 | 33 |
| Ferrosilicon[e] | 22 | 22 | [r]19 | [r]17 | 15 |
| Other[e] | 1 | 1 | 1 | 1 | 1 |
| Total[5] | 60 | 60 | 53 | 42 | [7]50 |
| Canada: Electric furnace: | | | | | |
| Ferromanganese[e] [8] | 120 | 152 | 118 | 128 | 130 |
| Ferrosilicon | 128 | [e]116 | 94 | [e]88 | 93 |
| Silicon metal | 31 | [e]30 | 28 | [e]28 | 28 |
| Other[e] [9] | 31 | -- | -- | -- | -- |
| Total[5] | 310 | [e]298 | 239 | [e]244 | 250 |
| Chile: Electric furnace: | | | | | |
| Ferromanganese | 6 | 3 | 6 | 5 | 5 |
| Silicomanganese | (4) | NA | NA | NA | NA |
| Ferrosilicon | 3 | 2 | 5 | 7 | 6 |
| Other | 1 | 2 | 2 | 2 | 2 |
| Total[5] | 9 | 6 | 13 | 15 | 14 |
| China: Furnace type unspecified:[e] [10] | | | | | |
| Ferromanganese[8] | 580 | 520 | 540 | 540 | 540 |
| Ferrosilicon | 215 | 215 | 215 | 215 | 215 |
| Silicon metal | 24 | 24 | 24 | 24 | 24 |
| Ferrochromium[11] | 130 | 130 | 130 | 130 | 130 |
| Other[9] | 80 | 80 | 80 | 80 | 80 |
| Total[5] | 1,029 | 970 | [r]990 | [r]990 | 990 |
| Colombia: Electric furnace, ferrosilicon[e] [12] | 1 | 1 | 1 | 1 | 1 |
| Czechoslovakia: Electric furnace: | | | | | |
| Ferromanganese[e] [8] | 110 | [r]105 | [r]103 | [r]96 | 103 |
| Ferrosilicon[e] | 35 | [r]33 | [r]33 | [r]31 | 33 |
| Silicon metal[e] | 6 | [r]5 | [r]5 | [r]4 | 5 |
| Ferrochromium[e] | 30 | [r]28 | [r]28 | [r]26 | 28 |
| Other[e] [9] | 10 | 10 | 10 | [r]9 | 10 |
| Total[5] [13] | 191 | [r]181 | 179 | 166 | [7]177 |
| Dominican Republic: Electric furnace, ferronickel | [r]55 | 16 | 58 | 71 | 76 |
| Egypt: Electric furnace, ferrosilicon | 6 | 7 | 7 | 8 | 8 |
| Finland: Electric furnace, ferrochromium | 57 | 60 | 65 | 65 | 66 |

See footnotes at end of table.

## Table 9.—Ferroalloys: World production, by country, furnace type, and alloy type[1] —Continued

(Thousand short tons)

| Country, furnace type,[2] and alloy type[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| France: | | | | | |
| Blast furnace: | | | | | |
| Spiegeleisen[e] | 1 | 1 | 1 | 1 | 1 |
| Ferromanganese | 344 | 365 | 297 | 362 | 364 |
| Electric furnace: | | | | | |
| Silicomanganese[14] | 11 | 32 | 36 | 38 | 39 |
| Ferrosilicon | 208 | 186 | 212 | 226 | 226 |
| Silicon metal | 66 | 63 | [e]62 | [e]55 | 55 |
| Ferrochromium[11] | 30 | 16 | 22 | 21 | 21 |
| Other[15] | 131 | 115 | 113 | 131 | 132 |
| Total[5] | 791 | 778 | 743 | 834 | 837 |
| German Democratic Republic: Electric furnace: | | | | | |
| Ferromanganese[e] [8] | 74 | 69 | 69 | [r]71 | 69 |
| Ferrosilicon[e] | 28 | 26 | 26 | [r]26 | 25 |
| Silicon metal[e] | 4 | 3 | 4 | 4 | 4 |
| Ferrochromium[e] | 22 | 22 | 19 | [r]21 | 21 |
| Other[e] [9] | 21 | 17 | 20 | 18 | 17 |
| Total[5] [13] | 149 | 138 | 141 | 140 | 137 |
| Germany, Federal Republic of: | | | | | |
| Blast furnace: | | | | | |
| Ferromanganese | 236 | 220 | 148 | 263 | 179 |
| Ferrosilicon[e] | 55 | 46 | 44 | [r]77 | 47 |
| Electric furnace:[e] | | | | | |
| Ferromanganese[8] | 21 | 21 | 19 | 28 | 34 |
| Ferrosilicon | 46 | 37 | 34 | 66 | 66 |
| Ferrochromium | 55 | 46 | 42 | 77 | 79 |
| Other[9] | 47 | 40 | 36 | 72 | 67 |
| Total[5] | 461 | 411 | 323 | 583 | 473 |
| Greece: Electric furnace: | | | | | |
| Ferrochromium | -- | -- | 20 | 36 | 39 |
| Ferronickel[e] | 56 | 56 | 55 | [r]58 | 61 |
| Total | 56 | 56 | 75 | 94 | 100 |
| Hungary: Electric furnace: | | | | | |
| Ferrosilicon | 12 | [e]12 | 11 | [e]10 | 10 |
| Silicon metal[e] | 2 | 2 | 2 | 2 | 2 |
| Other | 3 | [e]3 | 2 | 2 | 2 |
| Total[13] | 17 | 17 | 15 | 14 | 14 |
| Iceland: Electric furnace, ferrosilicon | 37 | [r]46 | 55 | 67 | [7]67 |
| India: Electric furnace: | | | | | |
| Ferromanganese | 227 | [r]174 | [e]169 | [r] [e]134 | 180 |
| Silicomanganese | 18 | 15 | [r] [e]3 | [r] [e]35 | 1 |
| Ferrosilicon | 67 | [r]44 | [e]52 | [r] [e]56 | 30 |
| Silicon metal | 4 | [e]4 | [e]4 | [e]3 | 3 |
| Ferrochromium | 35 | [r]46 | [e]65 | [r] [e]61 | 64 |
| Ferrochromium-silicon | 5 | [r] [e]5 | [e]3 | [r] [e]4 | 5 |
| Other | 10 | 15 | [r] [e]4 | [r] [e](4) | 1 |
| Total[5] | 365 | [r]304 | 296 | 295 | 284 |
| Indonesia: Electric furnace, ferronickel | 22 | 24 | 23 | 25 | 24 |
| Italy: | | | | | |
| Blast furnace: | | | | | |
| Spiegeleisen | (16) | (16) | (16) | (16) | -- |
| Ferromanganese | (16) | (16) | (16) | (16) | -- |
| Electric furnace: | | | | | |
| Ferromanganese | [r]80 | [r]82 | 69 | 56 | 61 |
| Silicomanganese | 60 | 64 | 41 | 80 | 55 |
| Ferrosilicon | 61 | 70 | 57 | 78 | 66 |
| Silicon metal[e] | 17 | 17 | 15 | 15 | 15 |
| Ferrochromium | 11 | 40 | 13 | 14 | 13 |
| Other[17] | 14 | 13 | 37 | 56 | 44 |
| Total[5] [17] | 242 | 286 | 232 | 300 | 255 |

See footnotes at end of table.

## Table 9.—Ferroalloys: World production, by country, furnace type, and alloy type[1] —Continued

(Thousand short tons)

| Country, furnace type,[2] and alloy type[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| **Japan: Electric furnace:** | | | | | |
| Ferromanganese | 626 | 593 | 429 | 535 | [7]487 |
| Silicomanganese | 312 | 297 | 245 | 257 | [7]239 |
| Ferrosilicon | 259 | 212 | 174 | 169 | [7]166 |
| Silicon metal | 13 | 9 | -- | -- | -- |
| Ferrochromium | 337 | 362 | 335 | 357 | [7]385 |
| Ferronickel | 269 | 236 | 199 | 239 | [7]250 |
| Other[e] | 4 | 7 | 5 | 7 | 4 |
| Total | 1,820 | 1,716 | 1,387 | 1,564 | [7]1,531 |
| **Korea, North: Furnace type unspecified:[e] [10]** | | | | | |
| Ferromanganese[8] | 77 | 77 | 77 | 77 | 77 |
| Ferrosilicon | 33 | 33 | 33 | 33 | 33 |
| Other[9] | 22 | 22 | 22 | 22 | 22 |
| Total | 132 | 132 | 132 | 132 | 132 |
| **Korea, Republic of: Electric furnace:** | | | | | |
| Ferromanganese | 75 | 66 | 58 | 65 | 67 |
| Ferrosilicon | 35 | 35 | 36 | 39 | 39 |
| Other | 30 | 37 | 48 | 55 | 61 |
| Total[5] | 141 | 139 | 142 | 159 | 166 |
| **Mexico: Electric furnace:** | | | | | |
| Ferromanganese | 145 | 155 | 153 | [e]176 | [7]169 |
| Silicomanganese | 28 | 34 | 46 | [e]47 | [7]44 |
| Ferrosilicon | 25 | 32 | 26 | [e]25 | [7]31 |
| Ferrochromium | 3 | 7 | 3 | [e]8 | [7]7 |
| Other | 2 | ([4]) | 1 | [e]2 | [7]([4]) |
| Total[5] | 204 | 227 | 229 | [e]258 | [7]250 |
| **New Caledonia: Electric furnace, ferronickel** | 121 | 120 | 93 | [r] [e]125 | 156 |
| **Norway: Electric furnace:** | | | | | |
| Ferromanganese | 257 | 224 | 312 | 252 | [7]237 |
| Silicomanganese | 236 | 238 | 215 | 278 | [7]267 |
| Ferrosilicon | 346 | 326 | 407 | 452 | [7]425 |
| Silicon metal | [e]61 | 72 | 85 | 100 | 112 |
| Ferrochromium | 13 | [r] [e]11 | [r] [e]4 | [r] [e]4 | -- |
| Ferrochromium-silicon | 1 | [e]1 | [r] [e]([4]) | [r] [e]([4]) | -- |
| Other[11] | 5 | 5 | 7 | 4 | 3 |
| Total[5] | 919 | 876 | 1,028 | 1,092 | [7]1,045 |
| **Peru: Electric furnace:** | | | | | |
| Ferromanganese | ([4]) | -- | ([4]) | ([12]) | ([4]) |
| Ferrosilicon | -- | -- | ([4]) | ([12]) | ([4]) |
| Total | ([4]) | -- | ([4]) | ([12]) | ([4]) |
| **Philippines: Electric furnace:[e]** | | | | | |
| Ferrosilicon | 25 | 30 | 22 | 20 | 21 |
| Ferrochromium | 11 | 13 | 24 | 36 | 44 |
| Total | 36 | 43 | 46 | 56 | 65 |
| **Poland:** | | | | | |
| Blast furnace: | | | | | |
| Spiegeleisen | 7 | 4 | 4 | 4 | 3 |
| Ferromanganese | 115 | 96 | 93 | 99 | 88 |
| Electric furnace: | | | | | |
| Ferromanganese[e] [8] | [r]45 | [r]39 | [r]53 | [r]53 | 54 |
| Ferrosilicon[e] | [r]47 | [r]41 | [r]57 | [r]56 | 57 |
| Silicon metal[e] | [r]10 | [r]8 | 11 | 11 | 12 |
| Ferrochromium[e] | [r]45 | [r]39 | [r]53 | [r]53 | 54 |
| Other[e] [9] | [r]15 | [r]14 | [r]19 | [r]19 | 18 |
| Total[5] [13] | [r]283 | [r]241 | 290 | 295 | [7]287 |
| **Portugal: Electric furnace:** | | | | | |
| Ferromanganese[e] [13] | 72 | 30 | 37 | 33 | 32 |
| Silicomanganese[e] [13] | 20 | 18 | 18 | 17 | 15 |
| Ferrosilicon[e] | 26 | 23 | 24 | 22 | 21 |
| Silicon metal[e] | 35 | 35 | 35 | 33 | 31 |
| Other[e] | ([4]) | ([4]) | ([4]) | ([4]) | ([4]) |
| Total[5] [13] | 153 | 106 | 115 | 105 | 99 |

See footnotes at end of table.

## Table 9.—Ferroalloys: World production, by country, furnace type, and alloy type[1] —Continued

(Thousand short tons)

| Country, furnace type,[2] and alloy type[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Romania: Electric furnace:[e] | | | | | |
| Ferromanganese | 77 | 83 | 88 | 96 | 88 |
| Silicomanganese | 36 | 39 | 42 | 45 | 43 |
| Ferrosilicon | 46 | 50 | 53 | 57 | 55 |
| Silicon metal | 4 | 4 | 4 | 5 | 5 |
| Ferrochromium | 40 | 43 | 46 | 50 | 49 |
| Total[5] | 203 | 218 | 234 | 253 | 240 |
| South Africa, Republic of: Furnace type unspecified:[e] [10] | | | | | |
| Ferromanganese | [r]500 | [r]490 | [r]160 | [r]210 | 315 |
| Silicomanganese | [r]50 | [r]40 | [r]160 | [r]210 | 315 |
| Ferrosilicon | [r]120 | [r]100 | [r]100 | [r]120 | 90 |
| Silicon metal | [r]30 | [r]30 | [r]25 | [r]35 | 40 |
| Ferrochromium | [r]830 | [r]520 | [r]800 | [r]980 | 920 |
| Ferrochromium-silicon | [r]20 | [r]20 | [r]15 | [r]35 | 30 |
| Other[19] | 1 | 1 | 1 | [r](4) | (4) |
| Total[5] | [r]1,550 | [r]1,200 | [r]1,260 | [r]1,590 | 1,710 |
| Spain: Electric furnace: | | | | | |
| Ferromanganese | 106 | 96 | [e]94 | [e]94 | 95 |
| Silicomanganese | 77 | 78 | [e]77 | [e]77 | 77 |
| Ferrosilicon | 94 | 70 | [e]68 | [e]66 | 67 |
| Silicon metal[e] | 20 | 20 | 19 | [r]66 | 68 |
| Ferrochromium | 19 | 17 | [e]15 | [e]15 | 19 |
| Other | 7 | 6 | [e]6 | [r] [e]1 | 4 |
| Total[5] [13] | 323 | 286 | 279 | 321 | 331 |
| Sweden: Electric furnace: | | | | | |
| Ferrosilicon | 21 | 16 | 21 | [r] [e]22 | 22 |
| Silicon metal | 16 | [e]18 | [e]18 | [e]18 | 18 |
| Ferrochromium | 161 | 129 | 132 | [e]138 | 136 |
| Ferrochromium-silicon | 25 | 22 | 20 | [e]22 | 22 |
| Other | 1 | 1 | 1 | [e]1 | 1 |
| Total[5] [13] | 223 | 185 | 192 | 200 | 199 |
| Switzerland: Electric furnace:[e] | | | | | |
| Ferrosilicon | 3 | 3 | 2 | 3 | 3 |
| Silicon metal | 2 | 2 | 2 | 2 | 2 |
| Total | 5 | 5 | 4 | 5 | 5 |
| Taiwan: Electric furnace: | | | | | |
| Ferromanganese | 21 | 21 | 24 | 22 | 20 |
| Ferrosilicomanganese | 16 | 23 | 20 | 25 | 25 |
| Ferrosilicon | 19 | 19 | 20 | 26 | 19 |
| Total[5] | 56 | 63 | 65 | 73 | 64 |
| Thailand: Electric furnace: | | | | | |
| Ferromanganese | (4) | -- | -- | -- | -- |
| Ferrosilicon | (4) | -- | -- | -- | -- |
| Total | [r]1 | -- | -- | -- | -- |
| Turkey: Electric furnace: | | | | | |
| Ferrosilicon | -- | [e]5 | [e]5 | 8 | 8 |
| Ferrochromium | 45 | 44 | 33 | 53 | 53 |
| Total | 45 | 49 | 38 | 61 | 61 |
| U.S.S.R.: | | | | | |
| Blast furnace: | | | | | |
| Spiegeleisen[e] | 55 | 55 | 55 | 55 | 55 |
| Ferromanganese[e] | 606 | 606 | 606 | 606 | 606 |
| Electric furnace:[20] | | | | | |
| Ferromanganese[e] | [r]474 | [r]496 | [r]551 | [r]661 | 744 |
| Silicomanganese[e] | 35 | 35 | 37 | 39 | 41 |
| Ferrosilicon[e] | 717 | 750 | 794 | 827 | 827 |
| Silicon metal[e] | 70 | 70 | 70 | 70 | 66 |
| Ferrochromium[e] | 441 | 457 | 457 | 463 | 463 |
| Ferrochromium-silicon[e] | 11 | 11 | 13 | 13 | 13 |
| Other[18] | 230 | 248 | 250 | 250 | 254 |
| Total[5] | [r]2,636 | [r]2,725 | 2,834 | 2,984 | 3,069 |

See footnotes at end of table.

## Table 9.—Ferroalloys: World production, by country, furnace type, and alloy type[1] —Continued

(Thousand short tons)

| Country, furnace type,[2] and alloy type[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| **United Kingdom:** | | | | | |
| Blast furnace, ferromanganese | 93 | 67 | 91 | 83 | 88 |
| Electric furnace, undistributed[9] | 14 | 12 | 14 | 14 | 13 |
| Total[5] | 107 | 79 | 106 | 97 | 101 |
| **United States: Electric furnace:[21]** | | | | | |
| Ferromanganese | 193 | 119 | 86 | [23]171 | [23]154 |
| Silicomanganese | 178 | 69 | W | ([23]) | ([23]) |
| Ferrosilicon | 580 | 299 | 314 | 490 | 442 |
| Silicon metal | 130 | 77 | 122 | 141 | 121 |
| Ferrochromium | 164 | 92 | 20 | [24]95 | [24]110 |
| Ferrochromium-silicon[25] | 62 | 27 | 16 | ([26]) | ([26]) |
| Other[27] | 219 | 186 | 198 | 190 | 151 |
| Total[5] | 1,521 | 819 | 757 | 1,088 | [7]977 |
| **Uruguay: Electric furnace, ferrosilicon** | ([4]) | ([4]) | ([4]) | ([4]) | ([4]) |
| **Venezuela: Electric furnace:** | | | | | |
| Ferromanganese | 2 | 2 | 2 | 2 | 2 |
| Silicomanganese | [r]2 | [r]2 | 10 | 10 | 8 |
| Ferrosilicon | [r]24 | [r]52 | 51 | 49 | 46 |
| Total[5] | [r]29 | [r]56 | 63 | 61 | 56 |
| **Yugoslavia: Electric furnace:** | | | | | |
| Ferromanganese | 56 | 43 | 44 | [r] [e]55 | 52 |
| Silicomanganese | 32 | 22 | 29 | [r] [e]42 | 42 |
| Ferrosilicon | 88 | 78 | 86 | [r] [e]105 | 108 |
| Silicon metal | 31 | 33 | 29 | [r] [e]41 | 41 |
| Ferrochromium | 76 | 56 | 70 | [r] [e]74 | 74 |
| Ferrochromium-silicon | 6 | 7 | 7 | [r] [e]7 | 7 |
| Other | 1 | 4 | 12 | [r] [e]12 | 12 |
| Total[5] | 291 | 243 | 277 | 335 | [7]330 |
| **Zimbabwe: Electric furnace:** | | | | | |
| Ferromanganese | 2 | 2 | 2 | 2 | 2 |
| Ferrosilicon | 28 | 14 | 30 | 47 | 47 |
| Ferrochromium | [r]203 | 198 | 174 | 196 | 198 |
| Total[5] | 233 | 215 | 207 | 245 | 248 |
| Grand total[5] | [r]15,833 | [r]14,352 | 14,240 | 16,165 | 16,103 |
| Of which: | | | | | |
| Blast furnace: | | | | | |
| Spiegeleisen[29] | [r]63 | [r]60 | 60 | 60 | 59 |
| Ferromanganese[28] | [r]1,394 | [r]1,354 | 1,235 | 1,418 | 1,325 |
| Ferrosilicon | 55 | 46 | 44 | 77 | 47 |
| Total blast furnace | [r]1,512 | [r]1,460 | 1,339 | 1,550 | 1,431 |
| Electric furnace:[10] | | | | | |
| Ferromanganese[29] | [r]3,143 | [r]2,983 | 2,819 | 3,091 | 3,166 |
| Silicomanganese[29] [30] | [r]1,294 | [r]1,212 | 1,193 | 1,429 | 1,433 |
| Ferrosilicon | [r]3,598 | [r]3,203 | 3,375 | 3,787 | 3,666 |
| Silicon metal | [r]597 | [r]546 | 587 | 687 | 684 |
| Ferrochromium[31] | [r]2,920 | [r]2,516 | 2,694 | 3,155 | 3,160 |
| Ferrochromium-silicon[30] [31] | 140 | [r]96 | 80 | 89 | 87 |
| Ferronickel[32] | [r]526 | [r]456 | 437 | 528 | 577 |
| Ferrosilicomanganese | 16 | 23 | 20 | 25 | 25 |
| Other[33] | [r]906 | [r]798 | 887 | 961 | 920 |
| Undistributed | 27 | 27 | 29 | 28 | 28 |

See footnotes at end of table.

### Table 9.—Ferroalloys: World production, by country, furnace type, and alloy type[1] —Continued

(Thousand short tons)

| Country, furnace type,[2] and alloy type[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Total electric furnace[5] | [r]13,167 | [r]11,810 | 12,121 | 13,780 | 13,745 |
| Furnace type unspecified: | | | | | |
| Ferromanganese[10] | 1,157 | 1,087 | 777 | 827 | 932 |

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Table includes data available through July 15, 1986.

[2] To the extent possible, ferroalloy production of each country has been separated according to the furnace type from which production is obtained; production derived from metallothermic operations is included with electric-furnace production.

[3] To the extent possible, ferroalloy production of each country has been separated so as to show individually the following major types of ferroalloys: spiegeleisen, ferromanganese, silicomanganese, ferrosilicon, silicon metal, ferrochromium, ferrochromium-silicon, and ferronickel. Ferroalloys other than those listed that have been identified specifically in sources, as well as those ferroalloys not identified specifically but which definitely exclude those listed previously in this footnote have been reported as "Other." For countries for which one or more of the individual ferroalloys listed separately in this footnote have been inseparable from some other ferroalloys owing to the nation's reporting system, such deviations are indicated by individual footnotes. In instances where ferroalloy production has not been subdivided in sources, and where no basis is available for estimation of individual component ferroalloys, the entry has been reported as "Undistributed."

[4] Less than 1/2 unit.

[5] Data may not add to totals shown because of independent rounding.

[6] Data for year ending Nov. 30 of that stated.

[7] Reported figure.

[8] Includes silicomanganese.

[9] Includes ferrochromium-silicon and ferronickel, if any was produced.

[10] Although furnace type has not been specified for any ferroalloy production for China, North Korea, and the Republic of South Africa, all output of these countries has been included under "Electric furnace" (and metallothermic) output except for their production of ferromanganese, which is reported separately.

[11] Includes ferrochromium-silicon, if any was produced.

[12] Colombia is reported to produce ferromanganese also, but output is not reported quantitatively, and no basis is available for estimation.

[13] Totals for 1981-85 represent estimates for silicon metal plus reported totals for all other types.

[14] Includes silicospiegeleisen.

[15] Includes ferronickel, if any was produced.

[16] Revised to zero.

[17] Series excludes calcium silicide.

[18] Estimated figures based on reported exports and an allowance for domestic use.

[19] Ferrovanadium only; other minor ferroalloys may be produced, but no basis is available for estimation.

[20] Soviet production of electric furnace ferroalloys is not reported; estimates provided are based on crude source material production and availability for consumption (including estimates) and upon reported ferroalloy trade, including data from trading partner countries.

[21] U.S. production of ferronickel cannot be reported separately in order to conceal corporate proprietary information.

[22] U.S. output of ferromanganese for 1984 and 1985 includes silicomanganese and manganese metal.

[23] U.S. output of silicomanganese for 1984 and 1985 included with ferromanganese.

[24] U.S. output of ferrochromium for 1984 and 1985 includes ferrochromium-silicon, chromium briquets, exothermic chromium additives, other miscellaneous chromium alloys, and chromium metal.

[25] U.S. output of ferrochromium-silicon includes chromium briquets, exothermic chromium additives, other miscellaneous chromium alloys, and chromium metal.

[26] U.S. output of ferrochromium-silicon for 1984 and 1985 included with "Ferrochromium."

[27] Includes ferronickel.

[28] Spiegeleisen for the Federal Republic of Germany is included with "Blast furnace ferromanganese."

[29] Ferromanganese includes silicomanganese (if any was produced) for countries carrying footnote 8 on "Ferromanganese" data line.

[30] Includes silicospiegeleisen for France.

[31] Ferrochromium includes ferrochromium-silicon (if any was produced) for countries carrying footnote 11 on "Ferrochromium" data line.

[32] Other includes ferronickel production for France, Norway, the U.S.S.R., and the United States.

Yugoslavian ferrosilicon producers planned to implement production cutbacks late in the year because of power availability problems and for economic reasons. Yugometal, the state marketing entity, announced in July that the new Kosovo ferronickel smelter was expected to export at least 11,000 tons of contained nickel to Austria, the Federal Republic of Germany, and Italy. Albania raised the possibility of sending some of its large nickeliferous iron ore deposits to the Kosovo Province for smelting there. Albanian ore shipments would depend on Yugoslavia completing its part of the new rail link from Shkodra to Titograd.

## TECHNOLOGY

A novel application of plasma technology to metallurgical processes was reported in France. It involves the production of H-C FeMn via the blast furnace route. Société du Ferromanganese de Paris-Outreau (SFPO), believed to be the first company in the world to use plasma torches on a commercial-scale blast furnace, began this practice in the latter part of 1984. Modification to one of three existing blast furnaces at SFPO's Boulogne plant consisted of attaching a 1.5-MW megawatt plasma torch to each of three of the nine tuyeres of the furnace to superheat the blast. Each blast furnace has an annual capacity of 150,000 tons of ferromanganese. Coke consumption has been reduced up to 6% as a result of the installation. Since SFPO is a net producer of electricity and the price of electric power undergoes seasonal fluctuations, plasma usage at the Boulogne plant tends to be emphasized during the summer months when income from the plant's surplus electricity is at a minimum.[22]

Middleburg Steel & Alloys continued testing its experimental plasma furnace for ferrochromium production at its Krugersdorp plant in the Republic of South Africa. During initial trials, the 16-MV•A furnace was operated at a feed rate of about 4 tons per hour using a power input of 5 to 6 MW. Owing to downtime and interrupted operations, energy consumption was excessive, about 7-MWh per ton, or about twice that of the conventional SAEF. Subsequently, a number of changes were made in the system to improve efficiency of operation. More recently, the furnace was operated at 11 MW, which approaches maximum design capacity of 14 MW. The feed rate was 8 to 9 tons per hour. According to plant operators, energy consumption has been improved considerably, approaching that of a conventional furnace. Chromium recovery exceeds 90%, greater than that achieved in conventional smelting.[23]

The Bureau of Mines funded a research project on plasma smelting of Montana Stillwater chromite concentrates at the Mineral Resource Research Center of the University of Minnesota. A ferrochrome product was produced in the 200-kW furnace equipped with a hollow graphite electrode. The furnace is similar in design to Middleburg Steel & Alloys' 12- to 14-MW ASEA/MINTEK dc furnace developed at Krugersdorp.

The Center for Metals Production (CMP), administered by the Mellon Institute of Carnegie-Mellon University, Pittsburgh, PA, continued research in such areas as plasma technology, among others. The CMP was established in 1984 with a 5-year contract that averages $2.5 million per year from the Electric Power Research Institute (EPRI). EPRI, headquartered in Palo Alto, CA, is a nonprofit research and development organization. Its goal is to bring together electric utilities; energy intensive industries such as aluminum, ferroalloys, and steel; Government agencies; universities; and trade associations to do the type of front-end, collaborative research that has proven successful in Japan and other nations. The overall goal of this research effort is to help revive and strengthen the North American metals industry.

Japan's MITI has launched a national research project to develop a new process for ferrochromium production using alternate energy sources. The objective is to achieve production costs comparable to the cost of importing ferrochromium from the Republic of South Africa. Ferrochromium is normally produced in a SAEF. Of the three major Japanese steelmaking companies that have independently developed a new ferrochromium production process, Nippon Steel's appears to be the most promising. The process involves chromium ore smelting in a Linz-Donawitz converter by injection of powdered coal with oxygen and bottom blowing with argon to produce ferrochromium for argon-oxygen decarburization conversion to stainless steel. The new process is expected to lower the cost of ferrochromium production in Japan by 20% to 30%.

Mizushima Gokintetsu also in Japan, and a subsidiary of Kawasaki Steel, reported preparations to start using a coke-fed shaft furnace to produce H-C FeMn by a process similar to that of the blast furnace. The shaft furnace, converted from a SAEF at a cost of nearly $12 million, has a capacity of about 100,000 tons per year and represents about one-fourth of Japan's 1984 production of H-C FeMn. The shaft furnace is expected to lower costs below those of electric smelting by taking advantage of the availability and relatively low prices of reducing gases and other gases produced within the steelmaking complex where the shaft furnace is located. The shift from electric to shaft furnace smelting in Japan contrasts with the discontinuance of blast furnace smelting of ferromanganese in the United States nearly 10 years ago.

Another technological innovation in Japan reportedly is making it possible for steel mills to use manganese ore directly in the converter instead of ferromanganese. Information on the percentage breakdown of manganese ore and ferromanganese used in steelmaking in Japan is not known but some sources estimate that the share of ore will increase to 30% in the future.

Researchers at the U.S. Department of Energy's Argonne National Laboratory in Argonne, IL, have developed a two-step process to extract manganese and other metals from low-grade ores. The key element in the process is a mixture of chloride salts of magnesium, potassium, and sodium that melts at about 400° C and dissolves almost all of the manganese contained in the crushed ore. Unwanted materials remain in the depleted ore. A low voltage is then applied across the liquid mixture, and dissolved manganese is recovered in elemental form as deposits on carbon electrodes. The Government is currently assessing the possibility of adapting the process to deep-sea mining of metal-rich nodules known to rest on the ocean floor.[24]

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[1] Physical scientist, Division of Ferrous Metals.

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[15] ———. V. 56, No. 45, Nov. 11, 1985, p. 7.

[16] Metal Bulletin (London). No. 6980, Apr. 23, 1985, p. 9.

[17] ———. No. 7048, Dec. 24, 1985, p. 15.

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[21] Work cited in footnote 8.

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# Fluorspar

## By Lawrence Pelham[1]

Fluorspar was recovered by one major producer and three small producers. Domestic fluosilicic acid ($H_2SiF_6$) recovery, a byproduct of some phosphoric acid and hydrofluoric acid (HF) plants, increased 12% over revised 1984 production. In the chemical industry, fluosilicic acid continued to augment fluorspar as a source of fluorine.

The United States depended on foreign sources for over 90% of its fluorspar requirements. Imports and consumption decreased because of significant decreases in fluorspar consumption by HF and iron and steel producers and a substantial decrease in consumer stocks.

**Domestic Data Coverage.**—Domestic production data for fluorspar are developed by the Bureau of Mines from four separate, voluntary surveys of U.S. operations. Surveys are conducted to obtain fluorspar mine production and shipments, fluosilicic acid production, fluorspar briquet production, and fluorspar consumption. Of the five fluorspar mining operations to which a survey request was sent, 100% responded, representing 100% of the production shown in table 1. Of the 16 fluosilicic acid producers, 87% responded, representing 99% of the quantity reported. Of the five briquet producers, 80% responded, representing 78% of the quantity reported. The consumption survey was sent to approximately 140 operations quarterly and 40 additional operations annually. Of the operations surveyed quarterly, 55% responded for the first quarter, 74% responded for the second quarter; 42% responded for the third quarter; and 54% responded for the fourth quarter. Of the 40 operations surveyed annually, 50% responded. Together, quarterly and annual responses represented 100% of the apparent consumption data shown in table 1.

**Table 1.—Salient fluorspar statistics[1]**

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production: | | | | | |
| Mine production ____ short tons | 415,862 | 199,714 | W | W | W |
| Material beneficiated ____ do | 419,058 | 231,726 | W | W | W |
| Material recovered ____ do | 111,281 | 76,316 | W | W | W |
| Finished (shipments) ____ do | 115,404 | 77,017 | [e]61,000 | [e]72,000 | [e]66,000 |
| Value, f.o.b. mine ____ thousands | $18,412 | $13,293 | [e]$10,000 | W | W |
| Exports ____ short tons | 11,261 | 10,573 | 9,236 | 12,266 | 9,671 |
| Value ____ thousands | $1,194 | $1,084 | $962 | $1,292 | $1,063 |
| Imports for consumption ____ short tons | 826,783 | 543,723 | 453,314 | 703,711 | 552,959 |
| Value[2] ____ thousands | $104,938 | $67,665 | $47,032 | $65,241 | $49,639 |
| Consumption (reported) ____ short tons | 932,855 | 530,565 | 564,187 | 752,581 | 567,623 |
| Consumption (apparent)[3] ____ do | 897,572 | 618,493 | 613,705 | [r]742,431 | 682,965 |
| Stocks, Dec. 31: | | | | | |
| Domestic mines: | | | | | |
| Crude ____ do | 200,698 | 164,094 | W | W | W |
| Finished ____ do | 12,924 | 10,816 | W | W | W |
| Consumer ____ do | 216,207 | 207,880 | 99,253 | 120,267 | 46,590 |
| World: Production ____ do | [r]5,616,455 | [r]4,953,735 | 4,655,787 | [p]5,270,263 | [e]5,267,976 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Does not include fluosilicic acid ($H_2SiF_6$) or imports of hydrofluoric acid (HF) and cryolite.

[2]C.i.f. U.S. port.

[3]U.S. primary and secondary production plus imports, minus exports, plus adjustments for Government and industry stock changes.

**Legislation and Government Programs.**—At yearend, the National Defense Stockpile inventory was unchanged from 1984 levels at 895,983 short tons of acid grade and 411,738 tons of metallurgical grade. The stockpile goals for fluorspar remained at 1.4 million tons for acid grade and 1.7 million tons for metallurgical grade.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. The status of fluorspar was deferred until further detailed studies could be made. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

As in previous years, a 22% depletion allowance was granted against Federal income tax applied to the mining of domestic fluorspar compared with a 14% allowance for foreign production.

## DOMESTIC PRODUCTION

Illinois remained the leading producing State, accounting for over 90% of all U.S. shipments. Data on shipments of fluorspar by State and grade were withheld to avoid disclosing company proprietary data.

Ozark-Mahoning Co., the Nation's largest fluorspar producer, operated three mines and a flotation plant in Pope and Hardin Counties, IL. Hastie Trucking and Mining Co. operated near Cave-In-Rock, IL. Hastie mined very little ore but shipped metallurgical-grade fluorspar from its stockpile to consumers. Inverness Mining Co., a former producer, dried imported fluorspar at its facilities at Cave-In-Rock, IL, and East Liverpool, OH, for sale primarily to consumers in the ceramic industry.

In the West, J. Irving Crowell, Jr. and Son produced and shipped metallurgical-grade fluorspar from its Crowell-Daisy Mine in Nye County, NV. D&F Minerals Co. produced and shipped a small quantity of metallurgical-grade fluorspar from its Paisano Mines, south of Alpine, TX. The Spor Bros. Fluorine Mine in Millard County, UT, reported mining activity.

Reported shipments of fluorspar briquets for use in steel furnaces increased 47% to approximately 148,000 tons from a revised production of 101,000 tons in 1984. Fluorspar briquets were produced by two plants owned by Cametco Inc., one plant owned by Mercier Corp., one plant owned by National Briquetting Co., and one plant owned by Oglebay Norton Co. Oglebay Norton also dried, packaged, and shipped imported ceramic- and acid-grade fluorspar.

Fourteen plants processing phosphate rock for the production of phosphoric acid and two plants producing HF sold or used 75,000 tons of byproduct fluosilicic acid, which was equivalent to 132,000 tons of fluorspar, valued at $4.2 million. Fluosilicic acid sold or used in 1984 was revised to 67,000 tons. According to the U.S. Department of Commerce, domestic production of sodium silicofluoride (100% $Na_2SiF_6$) was 21,622 tons in 1984. Total shipments were 19,594 tons in 1984 valued at $5,336,000. Sodium silicofluoride was made primarily from fluosilicic acid, which was converted to sodium salt by reaction with sodium carbonate, sodium hydroxide, or sodium chloride.

In 1985, Moodie Minerals Exploration Co. invested capital into the Babb-Barnes Mine and mill at Salem, KY, and planned to resume production. The mine had been owned, but not operated, by the Marathon Oil Co. The mine was last operated by Frontier Resources Inc., which had closed the mine in 1978 for economic reasons.

## CONSUMPTION AND USES

Acid-grade fluorspar, containing greater than 97% calcium fluoride ($CaF_2$), was used as feedstock in the manufacture of HF, the key ingredient in the manufacture of fluorine chemicals for the aluminum, fluorochemical, and uranium industries. Ceramic-grade fluorspar, containing 85% to 95% $CaF_2$, was used in the ceramic industry for the production of glass and enamel, to make welding rods, and as a flux in making steel. Metallurgical-grade fluorspar, containing 60% to 85% or more $CaF_2$, was used primarily by the iron and steel industry as a flux.

Reported domestic consumption of fluorspar decreased 25% because of large decreases in the use of fluorspar for HF and iron and steel production. The HF and steel industries accounted for 72% and 25%, respectively, of reported consumption. According to the American Iron and Steel Institute (AISI), raw steel production decreased from 92.53 million tons in 1984 to 87.35 million tons in 1985. A comparison of the AISI data with fluorspar consumption data collected in the Bureau of Mines canvass of U.S. steel producers shows, on the average, a decreasing rate of fluorspar consumption per ton of raw steel produced during 1983-85; however, steel production in open-hearth furnaces showed an increasing rate of fluorspar consumption. On the basis of furnace type, the average fluorspar consumption per ton of raw steel was as follows:

| Type of furnace | Fluorspar consumption (pounds per short ton) | | |
|---|---|---|---|
| | 1983 | 1984 | 1985 |
| Open hearth | 6.44 | 8.61 | 10.78 |
| Basic oxygen | 4.19 | 3.99 | 2.68 |
| Electric | 3.80 | 2.94 | 2.08 |
| Industry average | 4.30 | 4.06 | 3.08 |

In the ceramic industry, fluorspar was used as a flux and as an opacifier in the production of flint glass, white or opal glass, and enamels. Fluorspar was used in the manufacture of glass fibers, aluminum, cement, and brick, and was also used in the melt shop by the foundry industry.

Seven companies produced HF in seven plants. The U.S. Department of Commerce, Bureau of the Census, reported that anhydrous, technical, and aqueous HF "produced and withdrawn from the system" was approximately 162,400 tons, compared with 168,100 tons reported at yearend 1984 but later revised to 190,134 tons. HF produced and consumed in the same plant in 1984 was reported as 48,348 tons.

The Harshaw Filtrol Partnership closed its anhydrous HF unit at its Harvard-Denison chemical manufacturing facility in Cleveland, OH. The HF operation was in need of a large capital investment to maintain a competitive and safe operating level, and the company felt that market conditions for the expenditure were unjustified.

The consumption pattern of HF was reported as follows: fluorocarbons, 41%; aluminum production, 31%; petroleum alkylation, 4%; stainless steel production, 4%; uranium processing, 4%; rare metals, 4%; other, including glass etching, fluoride salts, and herbicides, 12%.[2] Chlorofluorocarbons were produced by five companies. According to U.S. International Trade Commission data, production of trichlorofluoromethane (F-11) decreased 12% to 81,300 tons; dichlorodifluoromethane (F-12) output decreased 17% to 141,000 tons; and chlorodifluoromethane (F-22) production decreased 14% to 109,350 tons.

Another major use of HF was in the synthesis of fluorine chemicals used in aluminum reduction cells. An estimated 40 to 60 pounds of fluorine was consumed for each ton of aluminum produced. Aluminum fluoride was used by aluminum producers to lower the melting point and increase the conductivity of electrolytes in the smelting process. It was also used as a flux ingredient for the removal of magnesium in the refining of aluminum scrap. Aluminum fluoride was used by the ceramic industry for some body and glaze mixtures and in the production of specialty refractory products. It was used in the manufacture of aluminum silicates and in the glass industry as a filler.

HF was consumed in concentrating uranium isotope 235 for use as nuclear fuel. It was also used in stainless steel pickling, petroleum alkylation, glass etching, oil and gas well treatment, and in the manufacture of a host of fluorine chemicals used in dielectrics, metallurgy, wood preservatives, pesticides, mouthwashes and decay-preventing dentifrices, plastics, and water fluoridation.

Fluosilicic acid was used primarily in water fluoridation, either directly or after being processed to sodium silicofluoride, and by the aluminum industry.

Allied Corp. started up a commercial-scale plant at Metropolis, IL, to produce fluorinated carbon products. Allied reported that its fluorinated carbons, which are made by reacting carbon with elemental fluorine, are nonfusable powders with good chemical resistance, high thermal stability, a low coefficient of friction, and variable electrical resistivity. Fluorinated carbons were used as a cathode material in lithium cells and as a solid lubricant.[3]

### Table 2.—U.S. consumption (reported) of fluorspar, by end use

(Short tons)

| End use or product | Containing more than 97% calcium fluoride ($CaF_2$) | | Containing not more than 97% calcium fluoride ($CaF_2$) | | Total | |
|---|---|---|---|---|---|---|
| | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 |
| Hydrofluoric acid (HF) | 530,527 | 408,880 | -- | -- | 530,527 | 408,880 |
| Glass and fiberglass | 4,952 | 1,337 | 846 | 1,083 | 5,798 | 2,420 |
| Enamel and pottery | -- | -- | 1,619 | 1,211 | 1,619 | 1,211 |
| Welding rod coatings | 8,414 | 9,867 | 2,600 | 1,460 | 11,014 | 11,327 |
| Primary aluminum and magnesium | -- | -- | -- | W | -- | W |
| Iron and steel castings | 924 | -- | 15,591 | 8,689 | 16,515 | 8,689 |
| Open-hearth furnaces | -- | -- | 35,893 | 34,647 | 35,893 | 34,647 |
| Basic oxygen furnaces | -- | -- | 105,253 | 69,615 | 105,253 | 69,615 |
| Electric furnaces | 2,021 | 2,065 | 42,597 | 28,087 | 44,618 | 30,152 |
| Other | -- | -- | 1,344 | 682 | 1,344 | 682 |
| Total | 546,838 | 422,149 | 205,743 | 145,474 | 752,581 | 567,623 |
| Stocks, Dec. 31 | 70,446 | 37,732 | 49,821 | 8,858 | 120,267 | 46,590 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

### Table 3.—U.S. consumption (reported) of subacid grades of fluorspar in 1985, by end use

(Short tons)

| End use or product | Containing not more than 97% calcium fluoride ($CaF_2$) | | |
|---|---|---|---|
| | Flotation concentrates | Lump or gravel | Briquets or pellets |
| Chemicals and allied products: Welding fluxes | 1,460 | -- | -- |
| Glass, ceramic, bricks: | | | |
| Glass | 1,083 | -- | -- |
| Other glass, clay products | 1,211 | -- | -- |
| Primary metals: | | | |
| Iron and steel foundries | 122 | 8,541 | 26 |
| Steel mills: | | | |
| Basic oxygen furnaces | 1,685 | 25,012 | 42,918 |
| Electric furnaces | 1,814 | 25,075 | 1,198 |
| Open-hearth furnaces | 3,054 | 28,663 | 2,930 |
| Other identified end uses | 49 | 633 | -- |
| Total | 10,478 | 87,924 | 47,072 |

### Table 4.—U.S. consumption of fluorspar (domestic and foreign), by State

(Short tons)

| State | 1984 | 1985 |
|---|---|---|
| Alabama, Kentucky, Tennessee | 68,643 | 56,490 |
| Arizona, Colorado, Utah | 12,141 | 9,028 |
| Arkansas, Kansas, Louisiana, Missouri | 161,450 | 125,306 |
| California | W | W |
| Connecticut, Massachusetts, New York, Rhode Island | 6,540 | 4,108 |
| Illinois | 10,747 | 5,827 |
| Indiana | 37,919 | 37,306 |
| Michigan | 2,294 | W |
| New Jersey | W | W |
| Ohio | 72,723 | 36,538 |
| Oregon and Washington | W | W |
| Pennsylvania | 54,950 | 30,130 |
| Texas | 278,728 | 237,484 |
| West Virginia | 14,480 | 1,633 |
| Other[1] | 31,966 | 23,773 |
| Total | 752,581 | 567,623 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes Iowa, Maryland, Virginia, Wisconsin, and data indicated by symbol W.

## STOCKS

Fluorspar consumer stocks decreased 61% to about 47,000 tons.

## PRICES

Domestic producer prices of all grades of fluorspar and fluorspar briquets reported in the Engineering and Mining Journal (E&MJ) remained at 1984 levels. E&MJ yearend price quotations serve as a general guide but do not necessarily reflect actual transactions.

Yearend price quotations in the Chemical Marketing Reporter (CMR) were $0.6875 per pound for anhydrous HF and $43.00 per 100 pounds for aqueous HF, 70%, in tanks. The CMR yearend price for cryolite was $550 per ton. CMR yearend price quotations for fluosilicic acid were $151.00 per ton for 15-gallon drums, 30% basis, and $110.00 per ton for tanks, 23% basis. All of these prices were unchanged from those of 1984.

### Table 5.—Prices of domestic and imported fluorspar

(Dollars per short ton)

| | 1984 | 1985 |
|---|---|---|
| Domestic, f.o.b. Illinois-Kentucky: | | |
| Metallurgical: 70% effective $CaF_2$ briquets | 125 | 125 |
| Ceramic, variable calcite and silica: | | |
| 88% to 90% $CaF_2$ | 100 | 100 |
| 95% to 96% $CaF_2$ | 170 | 170 |
| 97% $CaF_2$ | 165-175 | 165-175 |
| Acid, dry basis, 97% $CaF_2$: | | |
| Carloads | 173 | 173 |
| 88% effective $CaF_2$ briquets | 179 | 179 |
| European and South African:[1] Acid, term contracts | 140-180 | 140-180 |
| Mexican:[2] | | |
| Metallurgical: | | |
| 70% effective $CaF_2$, f.o.b. vessel, Tampico | 80.06 | 80.06 |
| 70% effective $CaF_2$, f.o.b. cars, Mexican border | 75.63 | 75.63 |
| Acid, bulk: 97 + %, Mexican border | 108.33 | 108.33 |

[1] C.i.f. east coast, Great Lakes, and gulf ports.
[2] U.S. import duty, insurance, and freight not included.

Source: Engineering and Mining Journal, Dec. 1984 and 1985.

## FOREIGN TRADE

According to Bureau of the Census data, U.S. fluorspar exports of all grades decreased 21% and had an average value of $110 per ton. Synthetic cryolite exports decreased 24% to 13,000 tons, representing 15,600 tons of equivalent fluorspar, valued at $5.4 million.

Imports for consumption of fluorspar decreased significantly. Acid-grade imports decreased by 17%, and imports of subacid-grade material decreased by 34%. Imports from Mexico, the largest foreign supplier, were 51% of the combined fluorspar total. The Republic of South Africa supplied 33%; Spain, 6%; China, 4%; Italy, 3%; and Morocco, 3%. Small quantities were also imported from Canada, France, the Federal Republic of Germany, and the United Kingdom. The average unit value of imported acid- and subacid-grade fluorspar was $97.12 and $63.53, respectively.

U.S. import duties remained in effect for all grades of fluorspar. The duty was $1.875 per ton for acid grade and 13.5% ad valorem for ceramic and metallurgical grades.

Imports for consumption of HF decreased slightly to a quantity equivalent to about 157,000 tons of fluorspar. Imports for consumption of natural and synthetic cryolite decreased 27% and had an average value of $603 per ton. Cryolite imports represented 20,000 tons of equivalent fluorspar.

The United States also imported many fluorochemicals, including ammonium bifluoride, chlorodifluoromethane, dichlorodifluoromethane, fluorocarbon polymers, hexafluoropropylene, polytetrafluoroethylene, and trichlorodifluoromethane.

## Table 6.—U.S. exports of fluorspar, by country

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (short tons) | Value | Quantity (short tons) | Value |
| Australia | -- | -- | 33 | $3,287 |
| Canada | 11,863 | $1,188,601 | 8,503 | 851,036 |
| Dominican Republic | 317 | 82,759 | 1,018 | 185,447 |
| Mexico | -- | -- | 25 | 3,287 |
| Venezuela | 86 | 21,066 | 90 | 19,563 |
| Total | 12,266 | 1,292,426 | [1]9,671 | 1,062,620 |

[1]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

## Table 7.—U.S. imports for consumption of fluorspar, by country and customs district

| Country and customs district | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (short tons) | Value[1] (thousands) | Quantity (short tons) | Value[1] (thousands) |
| CONTAINING MORE THAN 97% CALCIUM FLUORIDE ($CaF_2$) |  |  |  |  |
| Canada: |  |  |  |  |
| Buffalo | -- | -- | 24 | $1 |
| Detroit | 259 | $25 | -- | -- |
| Laredo | 81 | 6 | 437 | 41 |
| Total | 340 | 31 | 461 | 42 |
| China: |  |  |  |  |
| Baltimore | 39 | 11 | -- | -- |
| New Orleans | -- | -- | 5,882 | 551 |
| Total | 39 | 11 | 5,882 | 551 |
| France: Houston | 113 | 37 | 517 | 199 |
| Italy: |  |  |  |  |
| Houston | 61,619 | 7,825 | 15,765 | 1,557 |
| New Orleans | -- | -- | 2,480 | 259 |
| Total | 61,619 | 7,825 | 18,245 | 1,816 |
| Mexico: |  |  |  |  |
| El Paso | 90,788 | 8,219 | 72,255 | 6,657 |
| Houston | -- | -- | 6,112 | 675 |
| Laredo | 120,437 | 11,125 | 95,580 | 8,967 |
| New Orleans | 15,612 | 1,646 | 3,451 | 194 |
| Nogales | -- | -- | 290 | 6 |
| Total | 226,787 | 20,990 | 177,688 | 16,499 |
| Morocco: New Orleans | -- | -- | 15,674 | 1,564 |
| South Africa, Republic of: |  |  |  |  |
| Houston | 44,675 | 3,656 | 36,772 | 3,259 |
| New Orleans | 140,096 | 14,833 | 132,245 | 13,598 |
| Philadelphia | 9,958 | 959 | 12,085 | 1,294 |
| Total | 194,729 | 19,448 | 181,102 | 18,151 |
| Spain: |  |  |  |  |
| Cleveland | 20,648 | 2,211 | 12,968 | 1,337 |
| New Orleans | 17,173 | 1,803 | 19,449 | 1,794 |
| Total | 37,821 | 4,014 | 32,417 | 3,131 |
| United Kingdom: Milwaukee | -- | -- | 24 | 2 |
| Grand total | 521,448 | 51,856 | 432,010 | 41,955 |

See footnote at end of table.

## Table 7.—U.S. imports for consumption of fluorspar, by country and customs district —Continued

| Country and customs district | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (short tons) | Value[1] (thousands) | Quantity (short tons) | Value[1] (thousands) |
| **CONTAINING NOT MORE THAN 97% CALCIUM FLUORIDE ($CaF_2$)** |  |  |  |  |
| Canada: |  |  |  |  |
| Buffalo | 425 | $39 | 284 | $19 |
| Detroit | 177 | 12 | 153 | 6 |
| Pembina | -- | -- | 97 | 11 |
| Total | 602 | 51 | 534 | 36 |
| China: |  |  |  |  |
| Baltimore | 30,473 | 2,460 | 16,831 | 1,334 |
| New Orleans | 20,602 | 1,409 | -- | -- |
| San Francisco | 11,453 | 966 | -- | -- |
| Total | 62,528 | 4,835 | 16,831 | 1,334 |
| Germany, Federal Republic of: |  |  |  |  |
| Chicago | -- | -- | 37 | 15 |
| Houston | 11 | 3 | -- | -- |
| Total | 11 | 3 | 37 | 15 |
| Italy: Los Angeles | 23 | 9 | -- | -- |
| Mexico: |  |  |  |  |
| Buffalo | 401 | 42 | 1,318 | 82 |
| Detroit | 2,544 | 202 | 2,555 | 187 |
| El Paso | 16,699 | 796 | 9,453 | 441 |
| Laredo | 39,097 | 3,067 | 23,204 | 1,325 |
| New Orleans | 50,120 | 3,425 | 57,148 | 3,754 |
| Philadelphia | 7,445 | 725 | 9,869 | 560 |
| Total | 116,306 | 8,257 | 103,547 | 6,299 |
| South Africa, Republic of: New Orleans | 2,793 | 230 | -- | -- |
| Grand total | 182,263 | 13,385 | 120,949 | 7,684 |

[1] Customs, insurance, and freight (c.i.f.) value at U.S. port.

Source: Bureau of the Census.

## Table 8.—U.S. imports for consumption of hydrofluoric acid (HF), by country

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (short tons) | Value[1] (thousands) | Quantity (short tons) | Value[1] (thousands) |
| Canada | 43,441 | $36,644 | 36,637 | $33,869 |
| France | 17 | 14 | -- | -- |
| Germany, Federal Republic of | 56 | 82 | 119 | 112 |
| Japan | 4,422 | 3,429 | 4,137 | 2,859 |
| Korea, Republic of | -- | -- | 17 | 13 |
| Mexico | 66,399 | 60,694 | 62,504 | 56,233 |
| Mozambique | -- | -- | 601 | 533 |
| Netherlands | -- | -- | 20 | 18 |
| Spain | 35 | 29 | 35 | 28 |
| Taiwan | -- | -- | 17 | 16 |
| United Kingdom | 61 | 48 | 324 | 336 |
| Total | 114,431 | 100,940 | 104,411 | 94,017 |

[1] Customs, insurance, and freight (c.i.f.) value at U.S. port.

Source: Bureau of the Census.

### Table 9.—U.S. imports for consumption of cryolite, by country

| Country | 1984 Quantity (short tons) | 1984 Value[1] (thousands) | 1985 Quantity (short tons) | 1985 Value[1] (thousands) |
|---|---|---|---|---|
| Brazil | 17 | $12 | -- | -- |
| Canada | 13,883 | 7,079 | 2,414 | $1,287 |
| China | 19 | 10 | -- | -- |
| Denmark | 2,724 | 2,018 | 3,737 | 2,492 |
| France | 256 | 295 | -- | -- |
| Germany, Federal Republic of | 444 | 377 | 666 | 380 |
| Greenland | 65 | 61 | -- | -- |
| Italy | -- | -- | 3,327 | 1,960 |
| Japan | 3,663 | 2,554 | 5,169 | 3,244 |
| Netherlands | 98 | 72 | 907 | 532 |
| United Arab Emirates | 830 | 446 | -- | -- |
| United Kingdom | 723 | 200 | 376 | 108 |
| Total | 22,722 | 13,124 | 16,596 | 10,003 |

[1] Customs, insurance, and freight (c.i.f.) value at U.S. port.

Source: Bureau of the Census.

## WORLD REVIEW

**Canada.**—Assessment and development work continued at Eaglet Mines Ltd.'s Quesnet Lake property in British Columbia. The large, low-grade deposit reportedly contained recoverable fluorspar, silver, lead, zinc, and molybdenum. Minworth Ltd., a British firm, continued development work to reopen a fluorspar mine near St. Lawrence, Newfoundland. The mine had been last operated in 1977 by the St. Lawrence Corp. and Newfoundland Fluorspar Ltd., formerly a subsidiary of Aluminum Co. of Canada Ltd.

**France.**—The Belgian firm Solvay & Cie. planned to spend approximately $10 million to increase production capacity of its fluorinated monomer and polymer complex in Tavaux, France. Plans were to increase vinylidene fluoride, used in the manufacture of fluorinated thermoplastic polymers and elastomers, from 1,650 tons per year to 5,500 tons and polyvinylidene fluoride (PVDF), a fire-retardant resin, from 1,650 tons to 2,500 tons by October 1986. Solvay has been the world's second largest producer of PVDF after Pennwalt Corp.[4]

**United Kingdom.**—Shell Chemicals UK Ltd. began expanding the capacity of its fluorochemicals production unit at Stanlow, Cheshire, by more than 50%. The unit, the largest of its kind in the world, has produced a variety of fluorinated compounds derived by halogen exchange chemistry. The expansion was to be completed during 1986.

### Table 10.—Sales of Mexican fluorspar, by grade

(Short tons)

| Grade | 1981 | 1982 | [r]1983 | [r]1984 | 1985 |
|---|---|---|---|---|---|
| Acid | 532,765 | 338,732 | 400,579 | 508,235 | 409,800 |
| Ceramic | 100,511 | 27,202 | 49,285 | 54,562 | 51,982 |
| Metallurgical | 250,121 | 120,478 | 117,190 | 230,375 | 309,490 |
| Submetallurgical | 211,505 | 116,030 | 93,563 | 117,113 | 57,779 |
| Total | 1,094,902 | 602,442 | 660,617 | 910,285 | 829,051 |

[r] Revised.

Source: Instituto Mexicano de la Fluorita A.C.

## Table 11.—Fluorspar: World production, by country[1]

(Short tons)

| Country[2] and grade[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina | 22,878 | [illegible],155 | 31,950 | 25,526 | 27,500 |
| Brazil (marketable): | | | | | |
| Acid grade | 39,932 | 35,274 | 47,399 | [e]49,600 | 51,800 |
| Metallurgical grade | 19,184 | 20,944 | 28,660 | [e]33,000 | 37,500 |
| Total | 59,116 | 56,218 | 76,059 | [e]82,600 | 89,300 |
| China:[e] | | | | | |
| Acid grade | 88,000 | 88,000 | 110,000 | 110,000 | 110,000 |
| Metallurgical grade | 440,000 | 440,000 | 440,000 | 606,000 | 606,000 |
| Total | 528,000 | 528,000 | 550,000 | 716,000 | 716,000 |
| Czechoslovakia[e] | 106,000 | 106,000 | 106,000 | 106,000 | 105,000 |
| Egypt | 590 | 99 | 13 | [e]55 | 55 |
| France: | | | | | |
| Acid and ceramic grade | 185,960 | 177,725 | 155,957 | 175,378 | 165,000 |
| Metallurgical grade | 96,452 | 90,825 | 60,488 | 80,469 | 77,200 |
| Total | 282,412 | 268,550 | 216,445 | 255,847 | 242,200 |
| German Democratic Republic[e] | 110,000 | 110,000 | 110,000 | 110,000 | 110,000 |
| Germany, Federal Republic of (marketable) | 79,155 | 86,685 | 88,964 | 87,744 | 88,000 |
| Greece[e] | [4]322 | 330 | 330 | 330 | 330 |
| India: | | | | | |
| Acid grade | 14,711 | 13,676 | [e]12,000 | [e]13,000 | 13,000 |
| Metallurgical grade | 5,924 | 6,294 | [e]5,000 | [e]6,000 | 6,000 |
| Total | 20,635 | 19,970 | [e]17,000 | [e]19,000 | 19,000 |
| Italy: | | | | | |
| Acid grade | 142,019 | 147,850 | 113,439 | 121,618 | 116,000 |
| Metallurgical grade | 39,018 | 36,180 | 82,409 | 85,904 | 83,000 |
| Total | 181,037 | 184,030 | 195,848 | 207,522 | 199,000 |
| Kenya: Acid grade | 105,849 | 97,804 | 65,129 | 51,343 | 55,000 |
| Korea, North: Metallurgical grade[e] | 44,000 | 44,000 | 44,000 | 44,000 | 44,000 |
| Korea, Republic of: Metallurgical grade | 7,125 | 4,042 | 7,012 | 5,150 | 5,500 |
| Mexico: | | | | | |
| Acid grade | 559,973 | 450,845 | 448,640 | 379,725 | [4]417,469 |
| Ceramic grade | 119,049 | 59,525 | 50,706 | 40,307 | [4]30,011 |
| Metallurgical grade | 338,409 | 182,983 | 80,469 | 235,079 | [4]297,897 |
| Submetallurgical grade[5] | 212,746 | 116,845 | 87,082 | 115,878 | [4]57,779 |
| Total | 1,230,177 | 810,198 | 666,897 | 770,989 | [4]803,156 |
| Mongolia: Metallurgical grade[e] | 656,000 | 739,000 | 772,000 | [r]816,000 | 816,000 |
| Morocco: Acid grade | 73,524 | 55,336 | 66,469 | 72,642 | 77,000 |
| Pakistan | [r]6 | [r]897 | 370 | 3,003 | 2,600 |
| Romania: Metallurgical grade[e] | 22,000 | 22,000 | 22,000 | 22,000 | 22,000 |
| South Africa, Republic of: | | | | | |
| Acid grade | 497,819 | 323,882 | 256,563 | 318,892 | [4]341,949 |
| Ceramic grade | 6,744 | 10,613 | 7,061 | 4,963 | [4]6,310 |
| Metallurgical grade | 42,758 | 30,188 | 31,356 | 28,010 | [4]36,676 |
| Total | 547,321 | 364,683 | 294,980 | 351,865 | [4]384,935 |
| Spain: | | | | | |
| Acid grade | 235,471 | 173,289 | 210,265 | 279,128 | 248,000 |
| Metallurgical grade | 47,963 | 40,868 | 45,840 | 46,788 | 49,600 |
| Total | 283,434 | 214,157 | 256,105 | 325,916 | 297,600 |
| Thailand: | | | | | |
| Acid grade | 60,827 | 89,314 | 51,466 | 62,998 | 44,000 |
| Metallurgical grade | 173,405 | 194,099 | 176,324 | 253,783 | 220,000 |
| Total | 234,232 | 283,413 | 227,790 | 316,781 | 264,000 |
| Tunisia: Acid grade | 38,409 | 36,607 | 37,493 | 49,064 | 49,600 |
| Turkey: Metallurgical grade[e] | [4]2,189 | 2,200 | 2,200 | 2,200 | 2,200 |
| U.S.S.R.[e] | 585,000 | 595,000 | 595,000 | 606,000 | 617,000 |
| United Kingdom | [r]281,640 | [r]221,344 | 144,733 | 150,686 | 165,000 |
| United States (shipments) | 115,404 | 77,017 | [e]61,000 | [e]72,000 | 66,000 |
| Uruguay[e] | (6) | (6) | (6) | (6) | -- |

See footnotes at end of table.

Table 11.—Fluorspar: World production, by country[1] —Continued

(Short tons)

| Country[2] and grade[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Grand total | [r]5,616,455 | [r]4,953,735 | 4,655,787 | 5,270,263 | 5,267,976 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Table includes data available through May 13, 1986.

[2]In addition to the countries listed, Bulgaria is believed to have produced fluorspar, but production is not officially reported, and available information is inadequate for the formulation of reliable estimates of output levels.

[3]An effort has been made to subdivide production of all countries by grade (acid, ceramic, and/or metallurgical). Where this information is not available in official reports of the subject country, the data have been entered without qualifying notes.

[4]Reported figure.

[5]Same grade range as metallurgical but primarily contains greater quantities of silica impurities.

[6]Revised to zero.

## TECHNOLOGY

The Oak Ridge National Laboratory developed a new method of removing silica from silicon carbide powders using gaseous hydrogen fluoride.[5]

A 2-year study jointly funded by E. I. du Pont de Nemours & Co. Inc. and Allied determined that trichlorotrifluoroethane, a chemical solvent sold as fluorocarbon-113 and used to clean metals and sensitive equipment such as electronic components, did not appear to be a carcinogen, mutagen, or teratogen in animal tests or human experience.[6]

The National Institutes of Health and Du Pont continued sponsoring research to develop a "blood substitute," or oxygen-transport fluid, using perfluorochemicals. Alpha Therapeutics Corp., a U.S. subsidiary of Green Cross Corp. of Osaka, Japan, applied for Food and Drug Administration (FDA) approval of its perfluorochemicals, emphasizing its use in treating heart problems and cancer. Admamantech, a subsidiary of Sun Co. Inc., was also conducting studies on perfluorochemicals.

The FDA approved the sale of flecainide acetate, the first of a new electrophysiologic class of drugs for the treatment of irregular heart rhythms. It was the first fluorine containing drug approved for cardiac arrhythmias.[7]

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[1] Physical scientist, Division of Industrial Minerals.

[2] Chemical Marketing Reporter. V. 228, No. 10, 1985, p. 50.

[3] Chemical Week. V. 137, No. 23, 1985, p. 5.

[4] ———. V. 137, No. 3, 1985, p. 43.

[5] Work cited in footnote 4.

[6] Chemical & Engineering News. V. 63, No. 30, 1985, p. 17.

[7] ———. V. 63, No. 46, 1985, p. 61.

# Gallium

## By Deborah A. Kramer[1]

Domestic consumption of gallium increased moderately over that of 1984. No domestic primary gallium production was reported in 1985, and as a result, imports supplied most of the U.S. gallium demand. Gallium metal was used to produce gallium compounds, mainly gallium arsenide, for use in electronic devices, such as integrated circuits, light-emitting diodes (LED), and laser diodes.

**Domestic Data Coverage.**—Domestic consumption data for gallium are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the 53 operations to which a survey request was sent, 75% responded, representing 61% of the consumption shown in tables 1, 2, and 3. Consumption for the 13 nonrespondents was estimated using import data and information on domestic consumption trends.

**Table 1.—Salient U.S. gallium statistics**

(Kilograms unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Production[e] | 1,500 | 1,560 | -- | -- | -- |
| Imports for consumption | 5,536 | 5,199 | 7,294 | 9,669 | 7,961 |
| Consumption | 6,810 | 6,660 | 6,425 | 7,060 | 7,396 |
| Price per kilogram | $630 | $630 | $525 | $525 | $525 |

[e] Estimated.

**Legislation and Government Programs.**—The Environmental Protection Agency (EPA) issued final regulations under the Clean Water Act for specified nonferrous metals manufacturing operations. These regulations limit the discharge of pollutants by existing and new operations into navigable waters and into publicly owned treatment works. Primary and secondary gallium operations were included under the EPA regulations, and effluent discharges were to be regulated for arsenic, fluoride, lead, and zinc contaminants. Daily and monthly effluent limits for these elements varied according to type of manufacturing operation and effluent source.[3]

## DOMESTIC PRODUCTION

The U.S. gallium supply was obtained almost exclusively from imports. Eagle-Picher Industries Inc. recovered and refined gallium from primary and secondary material at its plant in Quapaw, OK.

Startup problems, including delays in equipment deliveries, bad weather, and extra time required to train operational crews, delayed the opening of Musto Exploration Ltd.'s primary gallium and germanium recovery plant near St. George, UT. The plant reportedly began limited production of 99.9%-pure gallium in October, but full-scale operation was postponed until 1986. Development continued on the Apex Mine ore zone, which reportedly contained recoverable quantities of copper, silver, and zinc, as well as gallium and germanium. Musto's plant was the only operation in the world to recover gallium or germanium as principal products, and when fully operational, the plant's annual production capacity was expected to be 10,000 kilograms of gallium and 17,900 kilograms of germanium.

According to a report published by the U.S. Geological Survey, most of the copper-rich ore at the Apex Mine was removed during previous mining operations, leaving behind iron-rich minerals containing most of the gallium and germanium. The remaining ore was defined as a goethite-limonite-hematite zone that contains local concentrations of jarosite, azurite, and malachite. Gallium was concentrated primarily in jarosite and in some limonite.[3]

## CONSUMPTION

Domestic gallium consumption continued to increase primarily for use in electronic devices. Over 95% of the gallium consumed was in the form of compounds, mainly gallium arsenide, for semiconductors, LED, and laser diodes.

Gallium arsenide continued to receive attention during the year because of its semiconductor applications. Ford Motor Co. announced that it would construct a $33 million facility in Colorado Springs, CO, to produce gallium arsenide integrated circuits. The plant, which was expected to have the capability to produce 25,000 gallium arsenide wafers per year, was scheduled to begin production by yearend. Ford planned to develop gate-array chips and static random-access memory chips at the new facility.[4]

Spectrum Technology Corp., a manufacturer of gallium arsenide wafers, planned an expansion to increase manufacturing output by 300%. Expansion completion at the company's Holliston, MA, headquarters was scheduled for June.

General Electric Co. (GE) planned to invest $3.5 million in advanced equipment for its gallium arsenide research and development center in Syracuse, NY. GE intended to increase design productivity and produce monolithic microwave integrated circuits. By establishing a 3-inch-wafer handling capability, the company expected to increase the number of designs that could be developed.[5]

**Table 2.—U.S. consumption of gallium, by end use**

(Kilograms)

| End use | 1983 | 1984 | 1985 |
|---|---|---|---|
| Specialty alloys | 43 | 42 | 65 |
| Electronics[1] | 5,915 | 6,320 | 7,071 |
| Research and development | 410 | 641 | 260 |
| Unspecified | 57 | 57 | -- |
| Total | 6,425 | 7,060 | 7,396 |

[1] Light-emitting diodes, semiconductors, and other electronic devices.

**Table 3.—Stocks, receipts, and consumption of gallium[1]**

(Kilograms)

| Purity | Beginning stocks | Receipts | Consumption | Ending stocks |
|---|---|---|---|---|
| 1984: | | | | |
| 97.0% to 99.9% | 110 | 39 | 44 | 105 |
| 99.99% | 4 | [r]307 | 254 | [r]57 |
| 99.999% | 4 | 20 | 20 | 4 |
| 99.9999% to 99.99999% | 1,712 | [r]5,790 | 6,742 | [r]760 |
| Total | 1,830 | [r]6,156 | 7,060 | [r]926 |
| 1985: | | | | |
| 97.0% to 99.9% | 105 | 65 | 65 | 105 |
| 99.99% | 57 | 396 | 419 | 34 |
| 99.999% | 4 | 14 | 16 | 2 |
| 99.9999% to 99.99999% | 760 | 6,919 | 6,896 | 783 |
| Total | 926 | 7,394 | 7,396 | 924 |

[r] Revised.
[1] Consumers only.

## PRICES

The price of 99.99999%-pure gallium metal, quoted in American Metal Market (AMM), remained at $525 per kilogram in 100-kilogram lots throughout the year. At yearend, prices for the following gallium materials were published by AMM, in dollars per kilogram: gallium metal, 99.99% pure, in 100-kilogram lots, $435; gallium metal 99.9999% pure, imported, $430 to $460; gallium oxide, 99.99% pure, imported, $380 to $400; and gallium oxide, 99.999% pure, $415.

Quoted prices of gallium materials were unchanged from yearend 1984, except for that of imported 99.9999%-pure metal, which increased by $50 to $60 per kilogram.

## FOREIGN TRADE

Export data for gallium metal and compounds were combined with data for other metal exports by the Bureau of the Census and could not be separately identified. Gallium metal and its compounds were exported in the form of electronic and electrical components.

Imports of gallium metal and waste and scrap declined moderately from those of 1984. Switzerland, France, and the Federal Republic of Germany, in decreasing order of receipts, continued to be the primary import sources, accounting for over 91% of U.S. imports. The average declared value of imported gallium increased to $433 per kilogram in 1985 from $419 per kilogram in 1984.

Beginning January 1, 1985, import duties for gallium compounds and gallium metal (TSUS 423.00 and TSUS 632.24, respectively) were 4% ad valorem for most favored nations (MFN) and 25% ad valorem for non-MFN.

### Table 4.—U.S. imports for consumption of gallium (unwrought, waste and scrap), by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Kilograms | Value | Kilograms | Value |
| Belgium-Luxembourg | -- | -- | 55 | $19,800 |
| Canada | 1 | $440 | 3 | 4,191 |
| China | 400 | 154,696 | -- | -- |
| France | 2,449 | 997,182 | 1,563 | 711,496 |
| Germany, Federal Republic of | 1,554 | 575,790 | 1,423 | 587,876 |
| Hungary | 168 | 61,430 | -- | -- |
| Japan | 89 | 40,317 | 105 | 29,351 |
| Malaysia | 5 | 1,630 | 40 | 14,400 |
| Netherlands | 131 | 49,120 | 50 | 19,725 |
| New Zealand | 132 | 53,030 | -- | -- |
| Suriname | -- | -- | 30 | 15,100 |
| Sweden | -- | -- | 201 | 112,302 |
| Switzerland | 4,088 | 1,938,711 | 4,268 | 1,847,744 |
| Taiwan | -- | -- | 50 | 17,000 |
| United Kingdom | 651 | 176,802 | 163 | 49,017 |
| Other | ʳ1 | ʳ883 | 10 | 19,080 |
| Total | 9,669 | 4,050,031 | 7,961 | 3,447,082 |

ʳRevised.

Source: Bureau of the Census.

## WORLD REVIEW

Data for world gallium production were unavailable, but world production of primary gallium was estimated to be about 30,000 kilograms.

**Japan.**—Gallium demand in Japan was estimated to be between 36,000 and 40,000 kilograms for production of gallium arsenide and gallium phosphide used for LED, laser and infrared diodes, and other semiconductor applications. A significant portion of this demand was supplied by scrap material generated by manufacturing operations. Limited availability of Bayer liquor at Sumitomo Chemical Co. Ltd.'s alumina plant, as a result of a reduced operating rate, prevented the company's Niihama primary gallium recovery facility from operating at its full 10,000-kilogram-per-year capacity. Sumitomo also refined crude gallium and recovered gallium from scrap at its Niihama facility.[6]

Dowa Mining Co. Ltd. announced plans to construct a new gallium recovery plant at Kosaka to increase its annual gallium production capacity to 10,000 kilograms. Plant completion was expected late in 1985 or early 1986. Dowa's annual capacity at yearend 1985 was estimated to be 5,000 kilograms for primary gallium recovery and 1,000 kilograms for scrap recycling.

**Switzerland.**—Alcan Aluminium Ltd. (Canada) purchased the production technology, inventories, and markets of Swiss Aluminium Ltd.'s (Alusuisse) gallium operation. Alusuisse operated a gallium refinery at Neuheusen with an annual capacity of 10,000 kilograms. It was expected that the processing equipment would be moved to the Alcan rolling mill at Rorschach after the acquisition was finalized.

## TECHNOLOGY

Scientists at the Bell Communications Research Center reportedly developed a technique called vapor levitation epitaxy (VLE) to float wafers on a cushion of gas while crystal layers are grown on the wafer. Gallium arsenide, indium phosphide, indium gallium arsenide, and indium gallium arsenide phosphide were grown by VLE. VLE reportedly produces exceptionally pure materials, which are important in fiber optics communication systems. The process also makes possible the growth of ultrathin layers of material, a few atoms thick, which are crucial to advanced optical device production. VLE reportedly allows the growth of structures that were not possible previously, and these structures can be grown on larger wafers with greater uniformity than was possible with existing production systems.[7]

Gould Inc. reportedly developed a gallium aluminum arsenide-gallium arsenide transistor, which the company claims is 3 times faster than conventional gallium arsenide devices and 10 times faster than conventional silicon devices. Use of a molecular beam epitaxy (MBE) process results in a structure that confines electron flow to a two-dimensional layer, providing lower noise levels. The new transistor was designed to replace gallium arsenide devices in very-high-frequency applications, such as satellites, radar, and electronic warfare systems, where low noise levels are required.

Using MBE techniques, scientists at Philips Research Laboratories in the United Kingdom reportedly produced gallium arsenide quantum well lasers that emit light in the visible part of the spectrum. Conventional gallium arsenide lasers emit light in the infrared wavelengths unless traces of aluminum are added to the active region to reduce the emission wavelength. In the production of the quantum well lasers, fast shutters are used to interrupt the molecular beams, allowing for changes in crystal composition within one atomic layer. One application for the laser already exists in optical information storage and retrieval systems, such as compact disk players.[8]

Researchers at the University of Illinois reportedly grew layers of gallium arsenide and gallium aluminum arsenide on silicon substrates by MBE. The researchers claim that performance of devices made from these wafers is almost identical to those fabricated from gallium arsenide substrates. Potential advantages of this technology include integration of high-speed gallium arsenide devices with silicon devices, the use of lower cost and high-quality silicon substrates, and development of gallium arsenide technology on larger silicon wafers. In the process, silicon substrates are cleaned to obtain a carbon-free surface by a series of alternating oxidation and oxide removal steps. Cleaned substrates, with a thin oxide layer, are loaded into an MBE system. Gallium arsenide growth is initiated by deposition of an arsenic layer, which provides nucleation sites for a layer of gallium. In this manner, atomic layers of gallium and arsenic are alternately deposited. Initially, a thin gallium arsenide layer is grown at a slow growth rate and low substrate temperature, after which the growth rate and substrate temperature are slowly raised to 1 micrometer per hour and 580° C, respectively.

Ferrofluidics Corp. was awarded a grant from the Israel-United States Binational Industrial Research Foundation for one-half the cost of the firm's $1.6 million gallium arsenide study program. The goal of the 3-year project was to develop a Czochralski gallium arsenide growing system, which was to be fully automated and would operate at low pressure. The company expected this system would produce improved material for use in both optical and semiconductor applications.

A newly formed company, Emcore Inc., offered modular production-scale equipment to produce gallium arsenide wafers. According to the company, the equipment can produce up to 40 wafers per day and can be altered to a customer's needs, unlike conventional equipment, which has a welded construction. Metal organic chemical vapor deposition (MOCVD) technology was used to fabricate the gallium arsenide wafers. In MOCVD, vapors of organic gallium and arsenic compounds are injected into a heated chamber where they decompose, and the gallium and arsenic deposit on a seed gallium arsenide wafer. By this method, deposition thickness can be carefully controlled, and chemical doping can be performed.

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[1] Physical scientist, Division of Nonferrous Metals.

[2] Federal Register. Nonferrous Metals Manufacturing Point Source Category; Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards. V. 50 , No. 183, Sept. 20, 1985, pp. 38276-38402.

[3] Bernstein, L. R. Geology and Mineralogy of the Apex Germanium-Gallium Mine, Washington County, Utah. U.S. Geol. Surv. Bull. 1577, 1986, 9 pp.

[4] Guiles, M. G. Ford To Begin Manufacturing Semiconductors. The Wall Street J., v. 205, No. 52, Mar. 15, 1985, p. 12.

[5] Solid State Technology. GE Expands GaAs R&D. V. 28, No. 12, Dec. 1985, pp. 18-19.

[6] Metal Bulletin Monthly (London). Rapid Expansion in Gallium. No. 174, June 1985, pp. 41-43.

[7] Photonics Spectra. Floating Along. V. 19, No. 6, June 1985, pp. 40-41.

[8] ———. More Progress in Quantum Well Lasers. V. 19, No. 11, Nov. 1985, p. 46.

# Gem Stones

## By Staff, Bureau of Mines

The value of gem stones and mineral specimens produced in the United States during 1985 was estimated to be $7.4 million, virtually the same as that of 1984. Amateur collectors accounted for much of the activity in many States. Small mine operators produced jade, opal, sapphire, tourmaline, and turquoise, which they sold mainly to wholesale and retail outlets, in gem and mineral shops, gem shows, and to jewelry manufacturers.

**Domestic Data Coverage.**—Domestic production data for gem stones are developed by the Bureau of Mines from the "Gem Stones" survey, a voluntary survey of U.S. operations. Of the 43 operations to which a survey request was sent, 33% responded. Production for the 29 nonrespondents was estimated using reported prior year production levels adjusted by trends in employment and other guidelines.

## DOMESTIC PRODUCTION

Mines and collectors in 46 States produced gem materials with an estimated value of $1,000 or more in each State. Ten States supplied 88% of the total value as follows: Arizona, $2.7 million; Nevada, $1.3 million; California, $550,000; Montana and Maine, $400,000 each; Oregon, $350,000; Wyoming, $225,000; and Arkansas, New Mexico, and Washington, $200,000 each. Estimated production increased 10% in California, 17% in Idaho, but decreased 11% in Montana and 13% in Oregon.

Lac Minerals Ltd. entered a joint venture with Superior Oil Co. in the continuing exploration of the Wyoming-Colorado border area near Tie Siding, WY, for diamond. The land holdings involve 63 unpatented claims and rights on an additional 2,500 acres leased from a Union Pacific subsidiary. Exploration revealed the existence of kimberlite pipes and dikes. A 3,000-short-ton bulk sample was processed through Superior's pilot plant at Fort Collins, CO, and found to be diamondiferous. A 500-carat sample of gem and industrial-quality diamonds was offered for sale by the parties, as part of the characterization studies, to determine the economic value.

A major new deposit of pink tourmaline (rubellite) associated with purple apatite was discovered at the Mount Rubellite Quarry near Hebron, ME. Purple and lavender apatite crystals also were found. The discovery could be the most significant gem stone find in Maine since the tourmaline discovery at Newry in 1972.

Exmin Corp. leased some lands in Minnesota's Morrison, Todd, and Wadena Counties to explore for diamonds. Some diamonds and kimberlite have been reported in Michigan and Wisconsin, and exploration continued in these two States in 1985.

A Texas partnership, Hanvey-Boulle Ltd., expressed a willingness to spend up to $2 million to take a core sample at the Crater of Diamonds State Park, Murfreesboro, AR, to determine if diamond mining is feasible. The State of Arkansas has final right of approval, and the Arkansas State Parks, Recreation, and Travel Commission appointed a special committee to examine any plans for commercial operations. A detailed proposal was requested from the firm by the committee. The firm indicated that the core sampling would involve drilling to a depth of 500 feet to determine the number of diamonds per hundred tons of soil. The firm also leased 3,000 acres of land surrounding the park, including several hundred acres leased from Anaconda Mining Co.[1]

## CONSUMPTION

Domestic gem stone output went to amateur and commercial rock, mineral, and gem stone collections, objects of art, and jewelry. Value of apparent consumption increased slightly to $3,008 million from that of 1984.

U.S. consumption of colored stones, led by emerald, ruby, and sapphire, decreased. Annual sales of emerald continued to be almost equal to those of ruby and sapphire combined. The value of all imported gem stones, other than diamond, decreased 10%, with other cut, set and unset, principally cultured pearls, decreasing 12%, followed by emerald with a 10% decrease.

According to data reported by the U.S. Department of Commerce, the sales value of merchandise sold by jewelry stores in 1985 increased 9%, to $11.1 billion, over that of the previous year. Jewelers of America Inc. data indicated a substantial gain in colored gem stones sales, compared with diamond sales, for the Nation, and even more strongly for the Southwest.

## PRICES

The U.S. price of 1.0-carat, D-flawless, investment-grade diamond fluctuated between $10,500 and $13,500 per carat, and at yearend was $12,750 per carat. However, only a few hundred of these perfect 1-carat stones have been available each year, and their value may have amounted to less than 0.2% of the total market.

Prices for colored stones experienced little change during the year.

### Table 1.—Prices of U.S. cut diamonds, by size and quality

| Carat weight | Description, color[1] | Clarity[2] (GIA terms) | Price range per carat[3] in 1985 | Median price per carat[3] | |
|---|---|---|---|---|---|
| | | | | November 1984 | August 1985 |
| 0.04-0.08 | G-I | $VS_1$ | $400- $590 | $490 | $482 |
| .04- .08 | G-I | $SI_1$ | 400- 500 | 450 | 440 |
| .09- .16 | G-I | $VS_1$ | 440- 750 | 560 | 550 |
| .09- .16 | G-I | $SI_1$ | 410- 600 | 475 | 460 |
| .17- .22 | G-I | $VS_1$ | 670- 1,200 | 835 | 810 |
| .17- .22 | G-I | $SI_1$ | 490- 1,150 | 690 | 675 |
| .23- .28 | G-I | $VS_1$ | 720- 1,400 | 965 | 950 |
| .23- .28 | G-I | $SI_1$ | 650- 1,300 | 770 | 755 |
| .29- .35 | G-I | $VS_1$ | 860- 1,300 | 1,260 | 1,235 |
| .29- .35 | G-I | $SI_1$ | 720- 1,500 | 1,050 | 1,010 |
| .46- .55 | G-I | $VS_1$ | 1,400- 2,300 | 2,000 | 1,950 |
| .46- .55 | G-I | $SI_1$ | 850- 1,845 | 1,545 | 1,500 |
| .69- .79 | G-I | $VS_1$ | 1,700- 2,900 | 2,500 | 2,460 |
| .69- .79 | G-I | $SI_1$ | 1,400- 2,450 | 1,950 | 1,910 |
| 1.00-1.15[4] | D | FL | 10,500-13,500 | 12,750 | 12,750 |
| 1.00-1.15 | E | $VVS_1$ | 6,600- 7,900 | 7,500 | 7,200 |
| 1.00-1.15 | G | $VS_1$ | 3,400- 5,200 | 4,200 | 4,120 |
| 1.00-1.15 | H | $VS_2$ | 2,400- 4,800 | 3,300 | 3,300 |
| 1.00-1.15 | I | $SI_1$ | 2,000- 3,800 | 2,600 | 2,600 |

[1] Gemological Institute of America (GIA) color grades: D—colorless; E—rare white; and G-I—traces of color.

[2] Clarity: FL—no blemishes; $VVS_1$—very, very slightly included; $VS_1$—very slightly included; $VS_2$—very slightly included, but more visible; and $SI_1$—slightly included.

[3] Jewelers' Circular-Keystone. V. 156, No. 14, Dec. 1985, p. 42; and v. 156, No. 12, Oct. 1985, p. 276. These figures represent a sampling of net prices that diamond dealers in various U.S. cities charged their customers during the month.

[4] The Diamond Registry Bulletin. V. 15, No. 1, Jan. 1985.

### Table 2.—Prices of U.S. cut colored gem stones, by size[1]

| Gem stone | Carat weight | Price range per carat in 1985[2] | Median price per carat,[1] [2] November 1984 |
|---|---|---|---|
| Amethyst | 10 | $6.50- $25 | $17 |
| Aquamarine | 5 | 50 - 200 | 150 |
| Citrine | 10 | 5 - 20 | 10 |
| Emerald: | | | |
| Colombian | 1 | 250 -5,000 | 1,500 |
| Zambian | 1 | 250 -4,000 | 1,400 |
| Commercial, 2d quality[3] | | 300 -1,600 | 550 |
| Garnet, tsavorite | 1 | 175 - 500 | 725 |
| Ruby: | | | |
| Medium to better | 1 | 460 -2,000 | 1,200 |
| Commercial, 2d quality[3] | 1 | 220 - 700 | 330 |
| Sapphire: | | | |
| Medium to better | 1 | 50 -1,500 | 700 |
| Commercial, 2d quality[3] | 1 | 165 - 480 | 220 |
| Tanzanite | 5 | 50 - 750 | 762 |
| Topaz | 5 | 10 - 500 | 210 |
| Tourmaline, green[4] | 5 | 50 - 250 | 132 |
| Tourmaline, pink[4] | 5 | 40 - 200 | 137 |

[1] Medium to better quality.

[2] Jewelers' Circular-Keystone. V. 155, No. 12, Dec. 1984, p. 44; and v. 156, No. 1, Jan. 1985, p. 52. These figures represent a sampling of net prices that colored stone dealers in various U.S. cities charged their cash customers during the month.

[3] The Gemstone Registry Bulletin. V. 2, No. 2, Jan. 1984, and v. 3, No. 1, Jan. 1985, p. 8.

[4] The Gemstone Registry Bulletin. V. 17, No. 3, Feb. 28, 1986, p. 8.

## FOREIGN TRADE

The declared customs value of U.S. imports of rough and polished natural diamond, excluding industrial diamond, was up slightly to $3.0 billion. Total polished diamond imports, principally from Israel, 29%; India, 19%; and Belgium, 13%; were valued at $2.7 billion. Imports in the over-0.5-carat category, mostly from Israel, 30%; Belgium, 28%; and Switzerland, 13%; increased 7% in value to $1.1 billion. The value of imports in the less-than-0.5-carat group, mostly from India, 31%; Belgium, 29%; and Israel, 29%; increased slightly to $1.6 billion. Imports of rough natural diamond, 53% from the Republic of South Africa, decreased 4% in caratage and slightly in value. A 5% increase in South African carat value, from $325 to $341, was indicated.

The total value of emerald imports decreased 10% to $139 million. The total value of ruby imports decreased 13% to $70 million, and sapphire imports decreased 15% to $71 million. Average carat values increased 45% for emerald to $51. Average carat values increased 15% for ruby to $19 and decreased 18% for sapphire to $19.

Export value of all gem materials other than diamond increased 12% to $60.1 million. Of this total, other precious and semiprecious stones, cut but unset, were valued at $35.4 million; other natural precious and semiprecious stones, not set or cut, $12.2 million; synthetic gem stones and materials for jewelry, cut, $4.1 million; pearls, natural, cultured, and imitation, not strung or set, $3.6 million; and other, $4.2 million. Reexports of all gem materials, other than diamond, decreased 24% to $39.9 million. Reexport categories were precious and semiprecious stones, cut but unset, $22.9 million; and other, $16.9 million.

### Table 3.—U.S. exports and reexports of diamond (exclusive of industrial diamond), by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (carats) | Value (millions) | Quantity (carats) | Value (millions) |
| Exports: | | | | |
| Belgium-Luxembourg | 128,521 | $65.0 | 179,829 | $82.3 |
| Canada | 19,043 | 11.0 | 23,012 | 12.2 |
| France | 2,153 | 7.1 | 1,763 | 8.3 |
| Germany, Federal Republic of | 3,677 | 3.7 | 2,937 | 2.5 |
| Hong Kong | 63,320 | 64.8 | 42,302 | 61.7 |
| Israel | 101,532 | 53.0 | 109,842 | 56.7 |
| Japan | 29,043 | 54.2 | 31,218 | 46.5 |
| Singapore | 3,734 | 9.2 | 2,039 | 4.4 |
| Sweden | 9 | (1) | 21 | (1) |
| Switzerland | 20,113 | 73.9 | 29,025 | 95.6 |
| Thailand | 3,813 | 2.4 | 5,226 | 2.8 |
| United Arab Emirates | 29 | (1) | -- | -- |
| United Kingdom | 5,707 | 14.2 | 3,966 | 4.0 |
| Other | 4,468 | 4.4 | 6,865 | 8.3 |
| Total | 385,162 | 362.9 | 438,045 | 385.3 |
| Reexports: | | | | |
| Belgium-Luxembourg | [2]1,072,640 | 57.4 | 839,257 | 56.7 |
| Canada | 7,834 | .6 | 4,243 | .3 |
| China | 17,784 | .7 | 8,120 | .4 |
| Germany, Federal Republic of | 32,530 | 1.5 | 53,318 | 1.6 |
| Hong Kong | 27,244 | 17.6 | 42,021 | 14.0 |
| India | 228,205 | 6.5 | 153,323 | 3.9 |
| Israel | 126,400 | 26.3 | 196,743 | 31.4 |
| Japan | 98,398 | 8.5 | 114,713 | 8.5 |
| Netherlands | 21,793 | 3.4 | 106,819 | 5.2 |
| Switzerland | 110,486 | 46.3 | 41,953 | 41.2 |
| United Kingdom | 93,442 | 32.6 | 297,044 | 12.2 |
| Other | 50,592 | 10.3 | 82,324 | 10.6 |
| Total | 1,887,348 | 211.7 | 1,939,878 | 186.0 |

[1] Less than 1/10 unit.

[2] Artificially inflated in 1984 by auction of approximately 1 million carats of U.S. Government stockpile industrial diamond stones with subsequent reexports as gem stones to Belgium-Luxembourg and India.

Source: Bureau of the Census.

### Table 4.—U.S. imports for consumption of diamond, by kind, weight, and country

| Kind, weight, and country of origin | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (carats) | Value[1] (millions) | Quantity (carats) | Value[1] (millions) |
| Rough or uncut, natural:[2] | | | | |
| Belgium-Luxembourg | 160,100 | $32.8 | 130,996 | $32.9 |
| Brazil | 1,431 | .3 | 90,280 | 6.6 |
| Cape Verde | -- | -- | 21 | (3) |
| Colombia | 216 | .2 | -- | -- |
| Congo | 12,977 | 4.4 | 80 | .2 |
| Guyana | 2,475 | .1 | 636 | (3) |
| Israel | 14,880 | 4.7 | 27,198 | 8.3 |
| Netherlands | 4,675 | 4.1 | 9,643 | 8.0 |
| South Africa, Republic of | 794,912 | 258.3 | 555,907 | 189.4 |
| Switzerland | 7,748 | 7.2 | 15,106 | 10.4 |
| United Kingdom | 22,125 | 4.6 | 116,601 | 52.0 |
| Venezuela | 34,811 | 2.3 | 21,036 | .8 |
| Other | 28,163 | 6.9 | 75,309 | 8.9 |
| Total | 1,084,513 | 325.9 | 1,042,813 | 317.5 |
| Cut but unset, not over 0.5 carat: | | | | |
| Belgium-Luxembourg | 1,424,655 | 433.6 | 1,466,325 | 444.8 |
| Brazil | 20,567 | 6.0 | 22,790 | 2.5 |
| Canada | 38,567 | 5.2 | 19,607 | 6.6 |
| Hong Kong | 100,017 | 20.3 | 146,416 | 39.4 |
| India | 3,107,794 | 544.8 | 2,667,906 | 486.8 |
| Israel | 1,113,127 | 399.5 | 1,237,123 | 448.2 |
| Malaysia | 21,949 | 7.8 | 17,772 | 6.0 |
| Netherlands | 56,924 | 23.5 | 85,811 | 26.9 |
| South Africa, Republic of | 38,301 | 23.8 | 48,074 | 16.9 |
| Switzerland | 56,670 | 23.8 | 153,329 | 38.7 |
| United Kingdom | 33,332 | 15.3 | 35,138 | 13.4 |

See footnotes at end of table.

## Table 4.—U.S. imports for consumption of diamond, by kind, weight, and country —Continued

| Kind, weight, and country of origin | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (carats) | Value[1] (millions) | Quantity (carats) | Value[1] (millions) |
| Cut but unset, not over 0.5 carat —Continued |  |  |  |  |
| Other | 44,030 | $16.0 | 68,754 | $22.2 |
| Total | 6,055,933 | 1,519.6 | 5,969,045 | 1,552.4 |
| Cut but unset, over 0.5 carat: |  |  |  |  |
| Belgium-Luxembourg | 410,638 | 379.8 | 369,838 | 314.7 |
| Hong Kong | 13,697 | 22.5 | 24,259 | 37.0 |
| India | 83,415 | 23.2 | 47,709 | 16.1 |
| Israel | 342,221 | 259.5 | 439,038 | 340.9 |
| Netherlands | 32,846 | 33.6 | 34,951 | 35.5 |
| South Africa, Republic of | 61,595 | 89.8 | 76,025 | 77.4 |
| Switzerland | 56,618 | 134.0 | 46,098 | 148.5 |
| United Kingdom | 34,643 | 68.9 | 46,832 | 75.1 |
| Other | 51,200 | 48.6 | 54,397 | 91.5 |
| Total | 1,086,873 | 1,059.9 | 1,139,147 | 1,136.7 |

[1] Customs value.
[2] Includes some natural advanced diamond.
[3] Less than 1/2 unit.

Source: Bureau of the Census.

## Table 5.—U.S. imports for consumption of natural precious and semiprecious gem stones, other than diamond, by kind and country

| Kind and country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (carats) | Value (millions) | Quantity (carats) | Value (millions) |
| Emerald: |  |  |  |  |
| Argentina | 12,474 | $1.3 | 122 | (1) |
| Belgium-Luxembourg | 10,092 | 2.8 | 106,895 | $3.4 |
| Brazil | 197,367 | 13.8 | 219,068 | 6.0 |
| Colombia | 271,559 | 48.9 | 197,249 | 56.1 |
| France | 11,456 | 2.5 | 20,928 | 3.8 |
| Germany, Federal Republic of | 52,883 | 2.4 | 26,176 | 1.7 |
| Hong Kong | 114,630 | 11.3 | 317,142 | 10.8 |
| India | 3,220,565 | 16.7 | 1,413,167 | 11.0 |
| Israel | 162,559 | 19.6 | 101,683 | 11.5 |
| Japan | 28,516 | 1.4 | 12,661 | 1.4 |
| Paraguay | 25,790 | (1) | -- | -- |
| South Africa, Republic of | 3,118 | .1 | 2,436 | .4 |
| Switzerland | 103,859 | 20.8 | 163,048 | 23.9 |
| Taiwan | 2,758 | (1) | 1 | (1) |
| Thailand | 116,812 | 4.5 | 74,418 | 1.1 |
| United Kingdom | 20,008 | 4.6 | 20,403 | 2.8 |
| Other | 55,709 | 3.9 | 65,916 | 5.1 |
| Total | 4,410,155 | 154.6 | 2,741,313 | 139.0 |
| Ruby: |  |  |  |  |
| Austria | 75,977 | .1 | 99 | (1) |
| Belgium-Luxembourg | 14,246 | 1.9 | 11,381 | 1.7 |
| Brazil | 10,712 | .1 | 18,993 | (1) |
| Colombia | 948 | .2 | 4,701 | .1 |
| France | 11,277 | 1.4 | 9,712 | 1.9 |
| Germany, Federal Republic of | 65,703 | 1.6 | 35,204 | 1.6 |
| Hong Kong | 71,857 | 5.5 | 110,033 | 3.7 |
| India | 226,782 | 1.8 | 221,923 | 1.3 |
| Israel | 99,663 | 2.1 | 42,921 | 1.2 |
| Japan | 33,146 | .6 | 21,242 | .5 |
| Switzerland | 81,943 | 12.6 | 296,877 | 15.6 |
| Thailand | 4,107,406 | 43.0 | 2,770,136 | 31.2 |
| United Kingdom | 21,208 | 6.1 | 33,713 | 6.4 |
| Other | 32,977 | 2.7 | 103,762 | 4.5 |
| Total | 4,853,845 | 79.7 | 3,680,697 | 69.7 |

See footnotes at end of table.

### Table 5.—U.S. imports for consumption of natural precious and semiprecious gem stones, other than diamond, by kind and country —Continued

| Kind and country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (carats) | Value (millions) | Quantity (carats) | Value (millions) |
| **Sapphire:** | | | | |
| Australia | 13,415 | $0.4 | 1,070 | [1]) |
| Austria | 1,186 | ([1]) | 122 | ([1]) |
| Belgium-Luxembourg | 20,436 | 1.8 | 32,047 | $0.9 |
| Brazil | 13,209 | .1 | 1,424 | ([1]) |
| Canada | 9,260 | .6 | 2,717 | .5 |
| Colombia | 1,647 | ([1]) | 2,057 | .1 |
| France | 11,185 | 2.5 | 18,973 | 1.9 |
| Germany, Federal Republic of | 67,298 | 1.8 | 32,028 | 1.2 |
| Hong Kong | 98,180 | 3.8 | 166,329 | 4.8 |
| India | 175,855 | 1.7 | 92,456 | 1.0 |
| Israel | 71,286 | 1.6 | 56,909 | 1.2 |
| Japan | 45,737 | 1.3 | 50,770 | .8 |
| Korea, Republic of | 22,478 | .1 | 2,664 | ([1]) |
| Singapore | 22,955 | .8 | 5,910 | .4 |
| Sri Lanka | 28,999 | 2.7 | 32,464 | 1.5 |
| Switzerland | 87,879 | 15.7 | 431,909 | 17.0 |
| Thailand | 2,917,584 | 39.2 | 2,765,371 | 32.4 |
| United Kingdom | 36,973 | 6.6 | 60,549 | 6.1 |
| Other | 32,816 | 2.3 | 72,000 | 1.0 |
| Total | 3,678,378 | 83.0 | 3,827,769 | 70.8 |
| **Other:** | | | | |
| Rough, uncut: | | | | |
| Australia | NA | 1.9 | NA | 1.5 |
| Belgium-Luxembourg | | .4 | | ([1]) |
| Brazil | | 14.0 | | 14.0 |
| Canada | | .1 | | ([1]) |
| Colombia | | 10.3 | | 9.8 |
| Hong Kong | | .6 | | .9 |
| Nigeria | | 2.6 | | .3 |
| Pakistan | | .5 | | .4 |
| South Africa, Republic of | | 1.6 | | .2 |
| Switzerland | | .5 | | .1 |
| United Kingdom | | .6 | | .8 |
| Zambia | | .4 | | .3 |
| Other | | 2.3 | | 4.8 |
| Total | NA | 35.8 | NA | 33.1 |
| Cut, set and unset: | | | | |
| Australia | NA | 2.8 | NA | 4.1 |
| Brazil | | 32.7 | | 10.5 |
| Canada | | 1.3 | | 1.0 |
| China | | 5.0 | | 4.5 |
| Germany, Federal Republic of | | 12.0 | | 12.3 |
| Hong Kong | | 20.4 | | 29.5 |
| India | | 6.1 | | 5.2 |
| Japan | | 240.7 | | 200.9 |
| Switzerland | | .7 | | 4.7 |
| Taiwan | | 5.4 | | 6.2 |
| Thailand | | 2.8 | | 3.4 |
| United Kingdom | | 1.5 | | 1.7 |
| Other | | 5.6 | | 12.6 |
| Total | NA | 337.0 | NA | 296.6 |

NA Not available.
[1] Less than 1/10 unit.

Source: Bureau of the Census.

### Table 6.—Value of U.S. imports of synthetic and imitation gem stones, including pearls, by country

(Million dollars)

| Country | 1984 | 1985 |
|---|---|---|
| Synthetic, cut but unset: | | |
| Austria | 0.8 | 0.4 |
| France | 1.4 | .9 |
| Germany, Federal Republic of | 5.5 | 5.5 |
| Japan | 1.4 | .1 |
| Korea, Republic of | 9.4 | 7.1 |
| Switzerland | 3.6 | 2.2 |
| Other | 1.7 | 1.4 |
| Total | 23.8 | 17.6 |
| Imitation: | | |
| Austria | 17.4 | 23.0 |
| Czechoslovakia | 1.8 | 1.7 |
| Germany, Federal Republic of | 6.0 | 8.9 |
| Japan | 4.5 | 6.3 |
| Other | 2.7 | 3.6 |
| Total | 32.4 | 43.5 |

Source: Bureau of the Census.

### Table 7.—U.S. imports for consumption of precious and semiprecious gem stones

(Thousand carats and thousand dollars)

| Stones | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Diamonds: | | | | |
| Rough or uncut[1] | 1,085 | 325,851 | 1,048 | 317,584 |
| Cut but unset | 7,148 | 2,579,466 | 7,108 | 2,689,178 |
| Emeralds: Cut but unset | 4,410 | 154,644 | 2,741 | 139,045 |
| Coral: Cut but unset, and cameos suitable for use in jewelry | NA | 3,120 | NA | 2,224 |
| Rubies and sapphires: Cut but unset | 8,532 | 162,677 | 7,509 | 140,618 |
| Marcasites | NA | 152 | NA | 256 |
| Pearls: | | | | |
| Natural | NA | 2,823 | NA | 2,997 |
| Cultured | NA | 240,439 | NA | 228,004 |
| Imitation | NA | 6,171 | NA | 8,396 |
| Other precious and semiprecious stones: | | | | |
| Rough, uncut | NA | 35,792 | NA | 33,168 |
| Cut, set and unset | NA | 90,421 | NA | 63,070 |
| Synthetic: | | | | |
| Cut but unset[2] | 52,484 | 21,368 | 52,164 | 17,590 |
| Other | NA | 2,410 | NA | 2,457 |
| Imitation gem stones | NA | 26,182 | NA | 35,333 |
| Total | XX | 3,651,516 | XX | 3,679,920 |

NA Not available. XX Not applicable.

[1] Includes 2,084 carats of other natural diamond, advanced, valued at $700,100 in 1984, and 630 carats valued at $1,062,100 in 1985.

[2] Quantity in thousands of stones.

Source: Bureau of the Census.

## WORLD REVIEW

De Beers Consolidated Mines Ltd.'s sales in 1985 through the Central Selling Organization were estimated to be $1.8 billion compared with $1.61 billion in 1984. Second half 1985 sales were unusually strong. Sales of colored gems also did very well.

Emeralds were produced in Australia, Colombia, Mozambique, Pakistan, the Republic of South Africa, the U.S.S.R., Zambia, and Zimbabwe. Sapphires were produced in Australia and Sri Lanka. Aquamarines were produced in Brazil and in very minor amounts in several other countries.

**Australia.**—Argyle Diamond Mines Joint Venture produced a total of about 17 million carats from its alluvial operation before the operation was closed in October. The second phase, production from the AK-1 kimberlite pipe, commenced on schedule in December. The firm estimated that the

AK-1 deposit would produce about 25 million carats per year for about 20 years.[2]

**Botswana.**—The new Jwaneng Mine expanded its diamond production. While mining was centered in the middle lobe, stripping proceeded on the northeastern lobe. The ore grade increased by 23% at the Jwaneng Mine, by 30% at the Letlhakane Mine, and by 8% at the Orapa Mine.

**Burma.**—The Ministry of Mines carried out exploration for diamonds by test pitting and drilling. It discovered 68 diamonds with a total weight of 65.31 carats in the period April 1, 1984, to December 31, 1984. Most of these were industrial diamonds.

Demand for Burmese rubies, particularly the bright red, continued to be strong. Very little material of comparable quality was available from other producers, such as Kenya, Tanzania, and Pakistan, in 1985. Rubies from Afghanistan were comparable but their availability was limited.

**Guinea.**—Diamonds from the Aredor project reached the New York market in midyear after some delay caused by adverse mining conditions. Société Mixte Aredor-Guinea was granted the sole right to explore and mine within its concession. Prior to this, private Guinean citizens could also mine in the concession. The private sector partners will market all the diamonds until the loans are paid off, after which the Government of Guinea will have the right to sell 30% of the rough gem diamonds and 50% of the rough industrial diamonds. The project was scheduled to produce from 250,000 to 500,000 carats per year.[3]

**India.**—The Indian diamond industry was almost exclusively dependent on imports of rough diamonds because domestic production usually totals under 15,000 carats. Imports of rough diamonds for Indian fiscal year 1983-84 totaled 28.4 million carats, the bulk of which came from De Beers. India's efforts to import diamonds directly from producers was of limited success. Some direct imports from Botswana, Ghana, and Sierra Leone were arranged. Indian exports of cut and polished diamonds for Indian fiscal year 1983-84 totaled 5.65 million carats, making India the world's leading diamond exporter, and diamonds India's largest single export item. Nearly 45% of the diamonds was exported to the United States. Japan was the second largest buyer, accounting for 11%, much less than that of the United States.

In response to foreign competition, the Indian industry announced plans to introduce foreign technology and machinery into what had been a cottage industry and was considering the production of sawn diamonds. The Government of India reduced duties on diamond cutting machinery and tools. Plans for a public-private joint venture to build a 1,300-acre self-contained diamond industrial park in Surat were announced.

India opened its first diamond exchange in Bombay on February 25. Titled the Bharat Diamond Bourse, it enrolled 150 members and provided them with customs clearance facilities and a vault for storing consignments.

The Government of India staged a series of income tax raids on diamond traders to seize records and diamond stocks as a part of its overall campaign against Government corruption and the underground economy. The industry responded by stopping all rough diamond imports and closing down operations. After a month of negotiations between the Government and the industry, activity resumed.[4]

**Israel.**—Imports of rough diamonds in the period January-October 1985 were $919 million, up 28.4% over the same period in 1984. Exports of cut and polished diamonds in the period January-October 1985 were $1,034 million, up 20.4% over the same period in 1984.

**Namibia.**—The Government-established Thirion commission of inquiry that had been investigating allegations of corruption and misappropriation of funds in the diamond industry for several years obtained evidence that the Diamond Board had not been exercising its regulatory powers over diamond mining as was originally intended. Interest centered on the alleged serious undervaluation of taxable diamond exports and on the excessive depletion of reserves in the diamond deposits. The Thirion commission's major purpose was to recommend ways of obtaining a greater degree of governmental control over the mining industry.

**Pakistan.**—The Pakistani Federal Bureau of Statistics reported that $1.5 million worth of gem stones was exported in the latest period, the fiscal year 1983-84, mainly to Hong Kong, the Federal Republic of Germany, the United States, and the United Kingdom. The exports, by type, included 130,282 kilograms of rough emeralds and 326 kilograms of cut emeralds, 6,062 kilograms of rough rubies and 3,912 kilograms of cut rubies, and 430 kilograms of rough sapphires and 865 kilograms of cut sapphires.

## Table 8.—Diamond (natural): World production, by country[1]

(Thousand carats)

| Country | 1981 |  |  | 1982 |  |  | 1983 |  |  | 1984[p] |  |  | 1985[e] |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Gem | Industrial | Total | Gem | Industrial | Total | Gem[2] | Industrial | Total | Gem[2] | Industrial | Total | Gem[2] | Industrial | Total |
| Angola | 1,050 | 350 | 1,400 | 915 | 310 | 1,225 | 775 | 259 | 1,084 | 750 | 250 | [e]1,000 | 375 | 250 | 625 |
| Australia | 21 | 184 | 205 | [r]274 | [r]183 | [r]457 | 3,720 | 2,480 | 6,200 | 3,414 | 2,276 | 5,690 | [3]4,235 | [3]2,824 | [3]7,059 |
| Botswana | 744 | 4,217 | 4,961 | 1,165 | 6,604 | 7,769 | 4,829 | 5,902 | 10,731 | 5,810 | 7,104 | 12,914 | 5,800 | 7,100 | 12,900 |
| Brazil | 163 | 926 | 1,089 | 80 | 450 | 530 | 80 | 450 | 530 | 200 | 550 | 750 | 200 | 800 | 1,000 |
| Central African Republic | 209 | 103 | 312 | 186 | 91 | 277 | 230 | 65 | 295 | 236 | 101 | 337 | 236 | 101 | 337 |
| China[e] | 190 | 760 | 950 | 200 | 800 | 1,000 | 200 | 800 | 1,000 | 200 | 800 | 1,000 | 200 | 800 | 1,000 |
| Ghana | 85 | 751 | 836 | 68 | 616 | 684 | 34 | 306 | 340 | 35 | 315 | [e]350 | 65 | 585 | 650 |
| Guinea[e] | 12 | 26 | 38 | 13 | 27 | 40 | 23 | 17 | 40 | [3]34 | [3]14 | [3]48 | 105 | 7 | [3]112 |
| Guyana[e] | 4 | 6 | 10 | [r]4 | [r]7 | 11 | 5 | [r]5 | [r]10 | [r]6 | [r]8 | [r]14 | 4 | 7 | 11 |
| India | 14 | 2 | 16 | 11 | 2 | 13 | 12 | 2 | 14 | [r]13 | 2 | 15 | 14 | 2 | 16 |
| Indonesia[e] | 3 | 12 | 15 | 3 | 12 | 15 | 5 | 22 | 27 | 5 | 22 | 27 | 5 | 22 | 27 |
| Lesotho | 49 | 4 | 53 | 39 | 3 | 42 | -- | -- | -- | -- | -- | -- |  |  |  |
| Liberia | 132 | 204 | 336 | 170 | 263 | 433 | 132 | 198 | 330 | 108 | 132 | 240 | 108 | 132 | 240 |
| Namibia | 1,186 | 62 | 1,248 | 963 | 51 | 1,014 | 915 | 48 | 963 | 884 | 46 | 930 | 894 | 47 | 941 |
| Sierra Leone | 208 | 97 | 305 | 203 | 87 | 290 | 242 | 103 | 345 | 240 | 105 | [e]345 | 240 | 105 | 345 |
| South Africa, Republic of: |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Finsch Mine | 1,002 | 3,463 | 4,465 | 847 | 3,003 | 3,850 | 1,765 | 3,278 | 5,043 | 1,714 | 3,184 | 4,898 | 1,770 | 3,184 | [3]4,954 |
| Premier Mine | 510 | 1,530 | 2,040 | 615 | 1,845 | 2,460 | 800 | 1,844 | 2,644 | 765 | 1,785 | 2,550 | 820 | 1,864 | [3]2,684 |
| Other De Beers' properties[4] | 1,603 | 1,069 | 2,672 | 1,359 | 906 | 2,265 | 1,400 | 569 | 1,969 | 1,452 | 593 | 2,045 | 1,500 | 569 | [3]2,069 |
| Other | 314 | 35 | 349 | 521 | 58 | 579 | 589 | 66 | 655 | 585 | 65 | 650 | 460 | 35 | 495 |
| Total | 3,429 | 6,097 | 9,526 | 3,342 | 5,812 | 9,154 | 4,554 | 5,757 | 10,311 | 4,516 | 5,627 | 10,143 | 4,550 | 5,652 | [3]10,202 |
| Swaziland | -- | -- | -- | -- | -- | -- | -- | -- | -- | 7 | 10 | 17 | 10 | 15 | 25 |
| Tanzania | 110 | 107 | 217 | 100 | 120 | [e]220 | 183 | 78 | 261 | 186 | 80 | 266 | 186 | 80 | 266 |
| U.S.S.R | 2,100 | 8,500 | 10,600 | 2,100 | 8,500 | 10,600 | 3,700 | 7,000 | 10,700 | 4,300 | 6,400 | 10,700 | 4,400 | 6,400 | 10,800 |
| Venezuela | 102 | 388 | 490 | 99 | 394 | [e]493 | 45 | 234 | 279 | 40 | 232 | 272 | 35 | 163 | 198 |
| Zaire | [r]360 | [r]6,801 | [r]7,161 | [r]308 | [r]5,856 | [r]6,164 | 3,355 | 8,627 | 11,982 | 5,169 | 13,290 | 18,459 | 5,493 | 14,124 | 19,617 |
| World total | [r]10,171 | [r]29,597 | [r]39,768 | [r]10,243 | [r]30,188 | [r]40,431 | 23,039 | 32,353 | 55,392 | 26,153 | 37,364 | 63,517 | 27,155 | 39,216 | 66,371 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through June 3, 1986. Total diamond output (gem plus industrial) for each country is actually reported except where indicated by a footnote to be estimated. In contrast, the detailed separate production data for gem and industrial diamond are Bureau of Mines estimates in the case of every country except Australia (1981-85), Central African Republic (1981, 1983-85), Guinea (1984), Liberia (1981, 1984), Sierra Leone (1981), and Venezuela (1981), for which source publications give details on grade as well as totals. The estimated distribution of total output between gem and industrial diamond is conjectural, and for most countries, is based on the best available data at time of publication.

[2] Includes near-gem and cheap-gem qualities.

[3] Reported figure.

[4] Other De Beers Group output from the Republic of South Africa includes Kimberley Pool, Koffiefontein Mine, and the Namaqualand Mines.

**South Africa, Republic of.**—The Minister of Finance announced a special temporary surcharge of 5% over and above the 20% surcharge already in effect on taxes paid by all domestic diamond and gold mines. The new surcharge was added in view of mining profits obtained owing to the favorable rand-dollar exchange rate in 1984. The Chamber of Mines, a mining trade association, responded by saying that any additional profits had been absorbed by increased capital expenditure.

De Beers reported about 95% of 1985 South African diamond production, or about 9.7 million carats. Its Finsch Mine, the largest diamond mine in the Republic of South Africa, produced 4.9 million carats, and its Premier Mine produced 2.7 million carats. Other sources indicate that in 1984, 73% of South African production was from Cape Province, 26% from Transvaal, and the balance from the Orange Free State.

The Finsch Mine worked slightly lower grade ore, in accordance with management's plan. The Premier Mine experienced no further collapse of the gabbro sill. Investigations indicated that retreatment of the mine's tailings pile appeared to be feasible, and the work was scheduled to begin during 1985.

**Swaziland.**—Trans Hex Co. was involved with its joint venture partner, the Swaziland Government, in a $5 million expansion of mining activity at its kimberlite pipe. The open pit extraction of industrial and low-quality gem diamonds, plus smaller amounts of good-quality gems, was expected to last at least 8 years. The expansion in capacity was expected to go on-stream in October 1985.

**Zaire.**—Société Minière de Bakwanga (MIBA) produced 6,896,000 carats in 1984 and exported 6,902,000 carats worth $57.9 million. MIBA invested $9.7 million in a new hydroelectric power station plus substantial sums on geological exploration and research, modernization of workers' housing, and improving the security of the operations.

**Zambia.**—The Government instituted new regulations on emerald mining in 1984, which were implemented in 1985. Prospecting and mining licenses must be obtained from the Ministry of Mines. Any company seeking a license must form a joint venture with the Government-owned Reserved Mineral Corp. holding a 55% majority of the shares. Several dozen local cooperatives have obtained licenses. The army and police have removed and will continue to remove illegal diggers from the emerald area until Reserved Mineral's new security service can take over completely.

## TECHNOLOGY

Sumitomo Electric Co. perfected a technique for the mass production of large industrial diamonds from graphite. The graphite was subjected to ultrahigh pressure in the range of 50,000 to 60,000 atmospheres at a temperature of 1,400° C to 1,600° C for 100 hours. Attaining this critical temperature and pressure on a consistent basis was difficult, but was achieved. Heretofore, only small-sized diamonds could be mass produced. The firm planned to underprice natural diamond slightly and make its sales mainly to the semiconductor and precision toolmaking industries. Although the firm had no immediate plans for the production of gem diamonds, this breakthrough could clearly result in the production of gem diamonds in the near future.[5]

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[1] Arkansas Gazette. Texas Firm Willing To Spend $2 Million on Tests at Crater of Diamonds. Oct. 12, 1985, p. 2.

[2] Industrial Minerals (London). World of Minerals. No. 220, Jan. 1986, p. 8.

[3] Jewelers' Circular-Keystone. Upfront. V. 156, No. 6, Apr. 1985, p. G.

[4] Shor, R. What if India Offers Quality Diamonds at Bargain Rates? Jewelers' Circ.-Keystone, v. 155, No. 8, June 1985, pp. 187-201.

[5] Industrial Minerals (London). Synthetic Diamond Breakthrough. No. 213, June 1985, p. 10.

# Gold

## By J. M. Lucas[1]

Weak gold prices during 1985 did not appear to have appreciably lessened exploration and development activity for new gold deposits both in the United States and in the rest of the world.

Domestic gold production, at nearly 2.5 million ounces,[2] reached its highest level since 1942. Substantial increases in production were registered in Australia, Brazil, Colombia, Japan, New Zealand, and Papua New Guinea.

Overall world gold consumption remained steady, with increased demand for gold jewelry offsetting declines in other sectors. The supply of new gold to the market decreased from that of 1984 as central banks and government-controlled investor institutions became net buyers of gold instead of net sellers.

**Table 1.—Salient gold statistics**

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Mine production thousand troy ounces | 1,379 | 1,466 | [r]2,003 | [r]2,085 | 2,475 |
| Value thousands | $633,918 | $550,968 | [r]$849,071 | [r]$751,833 | $786,345 |
| Percentage derived from: | | | | | |
| Precious metals ores | 71 | 80 | 83 | 87 | 93 |
| Base-metal ores | 27 | 17 | 14 | 11 | 5 |
| Placers | 2 | 3 | 3 | 2 | 2 |
| Refinery production: | | | | | |
| Domestic and foreign ores thousand troy ounces | 805 | 719 | 892 | [r]764 | 620 |
| Secondary (old scrap) do | 1,610 | 1,444 | 1,380 | 1,310 | 1,215 |
| Exports: | | | | | |
| Refined do | 5,238 | 1,637 | 1,881 | 3,482 | 2,888 |
| Other do | 1,199 | 1,333 | 1,258 | 1,499 | 1,078 |
| Imports for consumption: | | | | | |
| Refined do | 4,164 | 4,238 | 3,599 | 6,032 | 6,361 |
| Other do | 488 | 682 | 994 | 1,837 | 1,865 |
| Gold contained in imported coins do | 2,612 | 2,908 | 1,948 | 2,769 | 2,064 |
| Net deliveries from foreign stocks in Federal Reserve Bank do | 1,181 | 1,330 | -220 | 381 | 484 |
| Stocks, Dec. 31: | | | | | |
| Industry[1] do | 635 | 776 | [r]623 | [r]765 | 639 |
| Futures exchange do | 2,449 | 2,303 | 2,530 | 2,359 | 2,110 |
| Department of the Treasury: | | | | | |
| Gold medallion sales[2] do | 189 | 63 | 634 | 419 | 48 |
| Olympic gold coin sales do | -- | -- | -- | [3]156 | 24 |
| Consumption in industry and the arts do | 3,276 | 3,423 | 3,061 | [r]3,164 | 3,100 |
| Price:[4] Average per troy ounce | $459.64 | $375.91 | $424.00 | $360.66 | $317.66 |
| Employment[5] | 7,500 | 6,800 | [r]6,500 | [r]6,900 | 6,900 |
| World: | | | | | |
| Mine production thousand troy ounces | [r]41,250 | [r]43,127 | 44,996 | [p]46,408 | [e]48,217 |
| Official reserves[6] million troy ounces | 1,150.0 | 1,145.1 | 1,143.0 | [r]1,142.1 | 1,143.8 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Unfabricated refined gold held by refiners, fabricators, dealers, and U.S. Department of Defense.

[2] Sales program began July 15, 1980.

[3] Includes coins sold in 1982 and 1983 for delivery in 1984.

[4] Engelhard Industries quotation.

[5] Mine Safety and Health Administration.

[6] Held by market economy country central banks and governments and international monetary organizations. Source: International Monetary Fund.

**Table 2.—Volume of U.S. gold futures trading**

(Million troy ounces)

| Exchange | Location | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|
| Chicago Board of Trade | Chicago | 1.47 | 1.96 | 10.15 | 9.73 | 5.42 |
| Commodity Exchange Inc | New York | 1,041.67 | 1,212.40 | 1,038.28 | 911.55 | 788.40 |
| International Monetary Market[1] | Chicago | 251.82 | 153.35 | 99.40 | .88 | ([2]) |
| MidAmerica Commodity Exchange | do | 15.59 | 12.73 | 11.59 | 2.02 | 1.04 |
| Total |  | 1,310.55 | 1,380.44 | 1,159.42 | 924.18 | 794.86 |

[1] A division of the Chicago Merchantile Exchange.
[2] Less than 1,000 ounces traded. Trading ceased July 10, 1985.

**Domestic Data Coverage.**—Domestic mine production data for gold are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Typical of these surveys is the lode-mine production survey of gold, silver, copper, lead, and zinc mines. Of the 136 lode gold producers in operation to which a survey request was sent, 83% responded, representing 85% of the total lode-mine production of gold shown in tables 6 and 7. Production for the nonrespondents was estimated, using reported prior year production levels, adjusted by trends in employment and other guidelines such as company annual reports, the news media, and State agency reports.

**Legislation and Government Programs.**—More than 50 bills for gold and/or silver coins were introduced in the Congress in 1985; of this number, 2 were signed into law. The Statue of Liberty-Ellis Island Commemorative Coin Act, providing for the minting of gold and silver coins, became Public Law 99-61 on July 9. On December 17, the President signed the Gold Bullion Coin Act of 1985, thereby authorizing the U.S. Department of the Treasury to begin the minting of general-circulation gold coins. The coins, the first domestic legal tender gold coins to be minted in more than 50 years, were to be minted in four sizes containing from 0.10 to 1 troy ounce of gold. The enabling legislation, Public Law 99-195, specifically mandated that gold to be used in the minting come from U.S. mines and, in the absence of adequate available supplies at world prices, from Treasury bullion reserves.

With an executive order signed on October 1, the President banned imports of South African gold Krugerrand coins. The prohibition became effective on October 11, 1985.[3]

March 1 marked the completion of the Department of the Treasury's gold medallion sales program begun in mid-1980 and developed to reduce the outflow of U.S. dollars to foreign gold-coin-producing countries. During the life of the program, over 1.7 million ounces of gold in medallion form were sold. Legislation to extend the program for another 5 years was pending in the Congress.

On October 4, 1985, the Environmental Protection Agency (EPA) issued final rules establishing effluent limitations guidelines and standards limiting the discharge of pollutants into navigable waters and into publicly owned treatment works by existing and new sources conducting particular nonferrous metals manufacturing operations. Included in the rulemaking were primary and secondary precious metals operations.[4] Proposed effluent limitations guidelines and standards were issued by EPA on November 20, under the Clean Water Act, to limit effluent discharges of pollutants to waters of the United States from existing and new sources in the gold placer mining segment of the ore mining and dressing industry. EPA provided an extended comment period to allow affected miners adequate time to comment.[5]

Several States enacted legislation in 1985 affecting gold. On April 24, the Governor of Colorado approved legislation regulating the use of cyanide in Colorado mining operations.[6] In Washington State on May 21, the Governor signed legislation removing the State's sales tax on precious metal bullion and rare coins. The action was taken to align the State with practices in adjoining States and thereby discourage out-of-State commerce in these products.[7]

## DOMESTIC PRODUCTION

Despite lower gold prices than those of 1984, the search for new gold deposits, the development of new gold mines, and the expansion of existing operations combined to result in yet another excellent year for the Nation's gold mining industry. Nevada, with a 1985 gold production of over 1 million ounces, continued as the number one gold-producing State in the Nation.

Of the 2.5 million ounces of gold produced in the Nation, 88% was attributed to the 25 leading producers. The average recovery grade of gold ores processed from lode-mine sources was 0.06 ounce per short ton, while placer gravels yielded an average of 0.02 ounce per cubic yard washed.

Domestic refinery production from domestic and imported ores, concentrates, and semirefined products declined from that of 1984, reflecting, in part, a substantial decline in the processing of gold-bearing copper ores of both foreign and domestic origin. The production of refined gold from old scrap, over 1.2 million ounces, declined for the fifth consecutive year from the high production level set in 1980, a year when historically high prices for precious metals attracted a large volume of scrap to the market.

**Table 3.—Mine production of gold in the United States, by State**

(Troy ounces)

| State | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Alaska | 26,531 | 30,513 | 39,523 | [r]19,433 | 44,733 |
| Arizona | 100,339 | 61,050 | 61,991 | [r]54,897 | 52,053 |
| California | 6,271 | 10,547 | 33,443 | 35,858 | 165,101 |
| Colorado | 51,069 | 64,584 | 63,063 | 60,010 | 43,301 |
| Idaho | W | W | W | W | 44,306 |
| Michigan | -- | -- | -- | -- | W |
| Montana | 54,267 | 75,171 | 161,436 | 181,190 | 160,262 |
| Nevada | 524,802 | 757,099 | [r]960,657 | [r]1,020,546 | 1,276,114 |
| New Mexico | 65,749 | W | W | W | 45,045 |
| Oregon | 2,830 | W | 322 | W | W |
| South Carolina | -- | -- | -- | -- | W |
| South Dakota | 278,162 | 185,038 | 309,784 | 310,527 | 356,103 |
| Tennessee | W | -- | -- | -- | -- |
| Utah | 227,706 | 174,940 | 238,459 | W | 185,489 |
| Washington | W | W | W | W | W |
| Total | 1,379,161 | 1,465,686 | [r]2,002,526 | [r]2,084,615 | 2,475,436 |

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

**Alaska.**—Mineral exploration activity declined sharply in 1985, as indicated by a 59% reduction in expenditures directed toward exploration for all commodities, including gold. The decreased exploration activity was reportedly due to low base metal prices and budget cuts by several major mining companies that eventuated in some companies terminating their Alaska operations. Although overall expenditures for mineral development in Alaska declined, the largest increase registered, 11%, was directed toward the development of placer and lode gold projects. Gold production reported to the Bureau of Mines from Alaskan producers was nearly 45,000 ounces, compared with 19,433 ounces (revised) reported for 1984. However, an informal annual survey of Alaskan gold producers begun in 1981 and continued in 1985 by the Alaska State Division of Geological and Geophysical Surveys (DGGS) again suggested that a much larger total may have actually been produced. The State's survey indicated that about 190,000 ounces was recovered; this figure compares with similarly derived figures for 1982, 1983, and 1984 of 174,900, 169,000, and 175,000 ounces, respectively. The value of 1985 production was estimated by the State at $61 million, compared with about $63 million for 1984, and nearly $68 million for 1983. The lower 1985 value reflects again, as in recent years, gold's lower price, rather than reduced production.

Of the total indicated by the DGGS survey, an estimated 188,500 ounces of gold was produced by 266 placer mines operating in the State during 1985, an increase of 8% over 1984 estimated production. This increase, despite there being 15 fewer active operators, occurred primarily as a result of heightened activity at 4 large placer mines that together produced nearly 65,000 ounces of gold. Valdez Creek Mining Co. Inc.'s Valdez Creek Mine, for example, near Anchorage and the Denali Highway, increased output by over 10,000 to nearly 30,000 ounces. Low gold prices, regulatory restraints, water shortages, and exhaustion of reserves reportedly contributed to a slight decrease in production by the remaining operators. Environmental problems associated with placer mining were dominant.

Increasingly aggressive enforcement by State and Federal environmental regulatory agencies continued to involve greater numbers of operators.

Efforts by Alaska's placer miners to improve the quality of the process water discharged by their operations have in some instances resulted in a sharp increase in the amount of fine gold recovered. At several operations, technical innovations financed by the State's 1984 Placer Mining Demonstration Grant project resulted in both better gold recovery and cleaner water. The project, which had its first field demonstrations in 1985, awarded $2.7 million to qualifying miners; the focus was on fine gold recovery, water-use reduction, water-pollution control, and waste disposal. The maximum limit for an individual grant was $100,000, but miners could obtain a grant from both the Division of Natural Resources and the Department of Environmental Conservation.

At Klag Bay on Chichagof Island, south of Juneau, Queenstake Resources U.S.A. Inc., Vector Mining Co., and Exploration Ventures Co., which together form the Chichagof Joint Venture, concentrated their efforts on a two-phase underground drilling and drifting program at the old Chichagof gold mine, formerly one of Alaska's richest producers of lode gold. The partners budgeted $10 million for an accelerated development program in 1986. During the summer of 1985, Echo Bay Mines Ltd., of Edmonton, Alberta, Canada, acquired options from Barrick Resources Corp. to explore the Alaska Juneau (AJ) Mine near Juneau and the Treadwell Mine on nearby Douglas Island. Echo Bay intends to examine the feasibility of reopening these two former gold producers. The Planning Department of the City and Borough of Juneau conducted public hearings regarding its proposed Comprehensive Mining Ordinance aimed at regulating mining in areas within its jurisdiction, including both the AJ and the Treadwell. Debate on the issue continued through yearend.

Silverado Mines Ltd. and its partners Tri-Con Mining Inc. and Aurex Inc., a subsidiary of Marubeni American Corp., following delineation of new reserves and underground rehabilitation work, completed construction of a new 230-ton-per-day mill at the Grant Mine in midyear, and both the mill and mine began operations in October. At the end of December, however, Aurex withdrew from the project, reportedly because operating results were below its expectations; Silverado then suspended all operations. The company expected to reopen the mine at a later date.

Between September and November, Inspiration Resources Corp. of Claypool, AZ, conducted test production at its major offshore dredging operation, about 12 miles west of Nome. The mining rights were acquired earlier from Powerco Resources Corp. following its 1984 testing in the lease area. The company planned to begin full-scale dredging in 1986 at a rate of about 6,000 cubic yards per day. Onshore near Nome, Alaska Gold Co., the Northern Region's largest producer, processed 5,300 cubic yards per day with its Dredge No. 6 from late May to early November. Dredge No. 5 did not operate during the 1985 season, owing to a lack of thawed ground in which to operate.

In the Circle mining district of the Eastern Interior Region, Alaska's largest placer mining camp, 40 mining companies operated placer mines during the year. In the same district, Gold Dust Mining Co. placed into operation its jig recovery system that was manufactured in the Netherlands and transported to the site. The efficiency of the plant, employing a series of screens and jigs, exceeded company expectations, requiring up to 70% less water usage plus substantial recovery of fine gold in the 120- to 400-mesh range.

To the southwest, in the Mount McKinley-Denali area south along the Alaska Range, a number of mines were affected by court decisions voiding earlier National Park Service approvals of the Kantishna miners' operation plans. Overall, about 30 mines in 7 Alaskan National Parks were affected by the rulings, although most were able to complete the 1985 season.

West of Circle at Livengood, Livengood Placers Inc., 80% owned by Callahan Mining Corp., regained control of its placer property following the 1983 bankruptcy of the former lessee. During 1985, under an arrangement with the bankruptcy trustee, Livengood's contractor, Alaska Placer Development, did further cleanup on gravel left in the pit. Livengood continued to study alternatives for automated underground mining of the gold-bearing gravels on the property. Developments in Alaska were summarized in a draft report prepared by the DGGS.[8]

**Arizona.**—The production of gold in Arizona declined 5% from that of 1984, owing primarily to the continued decline in the production of gold-bearing ores at Arizona copper mines. Several precious metals miners in the State were affected by the year's weaker metals prices. After 4 years of pursuing ore bodies capable of being quickly and inexpensively brought into production, Phelps Dodge Corp. announced the closing of its Small Mines Div. Cumulative production by the division during its period of existence amounted to about 14,100 ounces of gold and 492,700 ounces of silver, with most of the production derived from small deposits in Cochise and Greenlee Counties. Tombstone Exploration Inc., following termination of mining operations in 1984, filed a bankruptcy petition under chapter 11 of the Federal bankruptcy laws. Posting debts of more than $350,000, the company indicated that the filing was a direct result of lower market prices for precious metals.

Exploration activity, although considerably less than that reported in recent years, continued, nevertheless, to be focused both on those many areas of the State where gold has been produced in the past as well as on those less well-explored areas, especially in western Arizona, where the potential for the discovery of detachment-hosted-type gold deposits, such as those recently recognized in Imperial County, CA, appeared to be geologically favorable. Cyprus Minerals Co. completed drilling its new Copperstone gold deposit at the north end of the Dome Rock Mountains near Parker in La Paz County. This detachment-hosted deposit was undergoing feasibility studies at yearend.

Although a number of old gold mines in the State's historic mining districts continued to be actively explored, there were others where work was curtailed owing to low metals prices. The interest of several companies appeared to be concentrated on old districts in the Bradshaw Mountains near Prescott in Yavapai County. The old lode and placer deposits formerly mined in the Big Bug District, east-southeast of Prescott, appeared to have garnered the attention of a number of companies. Joint venture partners Stan West Mining Corp. and Santa Fe Mining Inc. were reportedly pursuing interests around the old McCabe Mine. To the west, a few miles north of Congress, in Yavapai County, Echo Bay Inc., a subsidiary of Echo Bay Mines Ltd., completed a limited drilling program begun in 1984 on the old Congress Mines property. The company concluded at yearend that prevailing gold prices could not justify reopening the mine. In Yavapai County, near Wickenburg, McFarland & Hullinger, of Tooele, UT, and Global Energy Ltd., a Nevada corporation, reportedly had begun development at the old Oro Grande Mine.

**California.**—Gold mine developments in the State gained momentum in 1985 as several projects under construction development during the past 3 to 5 years commenced production or reached the final phase of development. These developments were reflected in the State's reported annual gold mine production, which nearly doubled in 1985, and had risen from about 4,100 ounces in 1980 to about 165,000 ounces in 1985. Capacity due on-stream in 1986 could more than double production in 1986 over that of 1985.

Following the discovery of its ore body in 1979 in a geological setting where previous gold exploration proved to be unproductive, the new McLaughlin Mine of Homestake Mining Co. poured its first bar of gold doré on March 4, 1985. The new mine and its attendant milling and administrative facilities is 60 miles north of San Francisco. At yearend, the new mine was approaching its design capacity of 1,050,000 tons per year, or 3,000 tons per day. From the pouring of the first bar through yearend, the mine produced 83,836 ounces of gold, including 4,922 ounces from ore mined in the preproduction period. The average cost of production was $422 per ounce. This high unit cost principally reflected startup costs. McLaughlin broke even in the fourth quarter of 1985 at a production cost of $322 per ounce. The mine was expected to achieve its design tonnage throughput early in 1986. The new $250 million facility was expected to yield 200,000 ounces of gold per year over the next 25 years; it represents the largest gold discovery in California in the 20th century.

Six miles north of Glamis, in Imperial County, Gold Fields Mining Corp., a wholly owned subsidiary of Consolidated Gold Fields PLC, of the United Kingdom, received final official approval in February 1985 to proceed with the final phases of construction at its Mesquite project. The new open pit, heap-leaching facility was scheduled to begin gold production in February 1986 at an expected annual rate of 130,000 to 160,000 ounces of gold, with cash costs, in 1985 terms, to be about $200 per ounce. The crushing plant commenced shakedown operations in October; leaching was expected to commence in January 1986. Ore was to be mined, prepared, and leached at a rate of 2 to 3 million tons per year. In November, the company announced that while development of the mine was under way, drilling in the vicinity of the mine to delineate additional reserves resulted in the discovery of three additional deposits bearing a geological similarity to the Mesquite deposit. Preliminary data on the new deposits indicated reserves of about 1.9 million ounces. The deposits are all near enough to the Mesquite facilities to be economically processed there.

At the Picacho Mine, east of Mesquite near the Picacho State Recreation Area on the Colorado River, Glamis Gold Ltd. of Vancouver, British Columbia, Canada, through its U.S. subsidiary Chemgold Inc., of Yuma, AZ, reported production of 28,000 ounces of gold in 1985. Gold production has increased significantly during each of the 3 years that this open pit, heap-leaching facility has operated. To the north, near Randsburg in Kern County, 125 miles northeast of Los Angeles, Chemgold continued work at its 1,000-acre Yellow Aster property. Air-track percussion drilling in the LaMonte discovery zone resulted in establishing reserves of nearly 500,000 tons, grading 0.062 ounce per ton. Estimated proven, probable, and percussion-drilled probable reserves at the Yellow Aster amounted to over 8 million tons averaging 0.028 ounce of gold per ton.

Also in Kern County, Cactus Gold Mines Co., a joint venture between CoCa Mines Inc. and Ventures Trident L.P., was reportedly moving forward with construction and preproduction stripping at a small high-grade gold deposit. The planned open pit, heap-leaching operation was reportedly expected to produce about 30,000 ounces annually beginning in 1986.

Eastward into San Bernardino County, Amselco Minerals Inc., a subsidiary of British Petroleum Corp. Ltd., was reportedly exploring the old Colosseum Mine, in the Clark Mountains near the Nevada border. A few miles to the south, Vanderbilt Gold Corp., following a brief hiatus in 1984, resumed production at its open pit-underground Morningstar Mine at Ivanpah Mountain. Gold and silver were recovered using heap leaching. Full gold production at a rate of about 2,500 ounces per month reportedly was expected to be reached during early 1986. To the west, near Edwards Air Force Base, Beaver Resources Inc., in partnership with Agean Resources Inc., a subsidiary of Glamis Gold, continued exploration, development, and test leaching at its Kramer Hills property. To the north, just south of the Nevada Weapons Center, Queenstake Resources Ltd., of Vancouver, Canada, concentrated exploration efforts at its Argus project toward evaluating the potential for heap-leachable, open pit reserves at three vein systems defined during its 1984 mapping and sampling program. Sampling was conducted both over and within the existing workings of several old gold mines. Drilling and trenching was also performed. Many of the properties in Imperial, San Bernardino, and Kern Counties are believed to be detachment-type deposits related to regional low-angle thrust faulting.

Considerable activity continued to be centered around the numerous old mines within California's famous Mother Lode District. Near Angel's Camp in Calaveras County, Carson Hill Gold Mining Corp., a subsidiary of Grandview Resources Inc. of Vancouver, Canada, elected to proceed with development of its 5,000-ton-per-day heap-leaching operation. The Carson Hill Mine, a former gold producer, has open pit reserves of 16 million tons grading 0.046 ounce per ton. Full-scale plant construction and mine preparation were scheduled to start in early 1986, with first gold recovery expected to start in mid-1986. A drilling program to extend the known ore body limits was under way at yearend.

To the south, corporate members of the ABM Mining Group Inc., also of Vancouver, pursued development at their Jamestown Mine in Tuolumne County and Pine Tree Mine in Mariposa County. Both properties were under development at sites formerly hosting producing gold mines. The Jamestown Mine of ABM's subsidiary, Sonora Gold Corp., was scheduled to begin production in late 1986 at a rate of 130,000 ounces per year. ABM's Goldenbell Resources Inc. was to begin construction at the Pine Tree Mine in late 1986, with startup expected to take place in late 1987. Production was expected to be 75,000 to 100,000 ounces per year. Another ABM affiliate, Inca· Resources Inc., pursued development at its Rich Gulch property, 22 miles west of Quincy in Plumas County. Production there was expected to begin in 1987. Also in Plumas County, Calgom Mining Inc. began full commercial production at its open pit, heap-leaching operation near Canyon Dam. The new mine, known as the Goldstripe, is a venture between NCA Mineral Inc., of Vancouver, and Calgom, a subsidiary of Sunbelt Mining Co., a wholly owned division of the Public Service Co. of New Mexico. Ore was being processed at the full planned capacity of 1,600 tons per day. Production was estimated to be about 20,000 ounces per year. To the south, in Sierra County, Brush Creek Mining & Development Co. Inc. continued production and development at its underground Brush Creek Mine and was proceeding with preparations to open two other nearby properties, the Gardner's Point Mine and the Gold Point Mine.

At its placer gold dredging operation near Marysville and the Yuba River, Yuba Placer Gold Co., a joint venture between Yuba Natural Resources Inc. and St. Joe Gold Co.'s Placer Service Corp., recovered about 23,000 ounces of gold during the fiscal year ending on October 31, an increase of 7,300 ounces over that of 1984. At yearend, the company was studying the feasibility of increasing the capacity of its dredge, the deepest digging gold dredge in the market economy countries. Numerous smaller dredging and placering operations were active in the State during the year.

**Colorado.**—In March, the State's largest gold producer, the Sunnyside Mine at Silverton, ceased mining and milling operations following financial difficulties stemming from low metals prices and the March 1984 decision by the mine's operators, Standard Metals Corp. of New York, to file for protection from its creditors under chapter 11 of the Federal Bankruptcy Code. In September, following approval by a Federal bankruptcy court, Standard Metals agreed to sell its interest in the mine to Echo Bay Mines Ltd. By yearend, Echo Bay was in the process of refurbishing the mine and expected to resume production by mid-1986. Echo Bay reportedly will operate the mine under the name of Sunnyside Gold Corp. Several other gold mining facilities in Colorado reportedly suspended operations in 1985. They include the joint operations of Hampton Gold Mining Areas PLC and Centennial Gold Corp. in Craig County; the Crystal Hill Mine and heap-leaching facility of Draco Mines at LaGarita; and Nerco Minerals Co.'s Victor Mine near Cripple Creek. At the Victor Mine, a joint venture between Nerco and Silver State Mining Corp., Nerco concentrated on renovating and expanding the mine's facilities to increase production. Limited production began during the last half of 1985 to test the new improvements; 6,000 and 2,000 ounces of gold and silver, respectively, were produced.

Galactic Resources Ltd., of Vancouver, was at yearend moving rapidly toward completion of construction at its large Summitville gold mine in the San Juan Mountains. The new Rio Grande County open pit, heap-leaching operation was due on-stream in early 1986 at a planned annual rate of about 120,000 ounces per year. Near Boulder, Cosmos Resources Ltd., of Vancouver, and the Steen family completed construction of their 50-ton-per-day mill and development of the underground workings at the Cash Mine at Gold Hill. Production of telluride ore was begun toward yearend. Cobb Resources Corp., of Albuquerque, NM, continued development work at its London Mine venture near Fairplay in Park County. Toward yearend, Cobb was negotiating with Houston Natural Gas Co. (HNG) to acquire HNG's 50% interest in the venture following HNG's earlier decision to concentrate its interests outside of hard minerals. Production was expected to begin in the fall of 1987.

In the Cripple Creek District, Cripple Creek and Victor Gold Mining Co., a joint venture between Texasgulf Minerals and Metals Inc. and Golden Cycle Gold Corp., began limited heap-leaching operations on approximately 3 million tons of old mine dumps within the district. The company also conducted an exploration drilling program on selected properties controlled by Texasgulf in the Cripple Creek area.

A number of former producing gold mines in the State underwent geological investigation or preproduction development in 1985. Gerber Minerals Corp. of Denver entered into a joint venture agreement with two limited partnerships to develop the old Gold King Mine property near Silverton. Also near Silverton, International North American Resources Inc. and P & G Mining Inc. reportedly formed a joint venture and conducted exploration and development aimed at returning the old Sultan Mountain gold and silver mine to productive status. Limited production was continued at the old Franklin Mine, near Idaho Springs, by Franklin Consolidated Mining Co. Inc.

**Idaho.**—In Valley County, Coeur d'Alene Mines Corp., of Wallace, continued construction and preproduction development at its Thunder Mountain property in the Payette National Forest, 40 miles east of McCall. Gold production at the open pit, heap-leaching facility was expected to begin in the spring of 1986 at a rate of 25,000 ounces per year. Climatological considerations dictate that a 4-month summer production season can be expected. The company estimated that as of June 30, 1985, proven, in-place minable ore reserves, at 1.788 million tons, contained an average of 0.095 ounce of gold per ton and 0.077 ounce of silver per ton. Exploration drilling on an adjoining area known as Lightning Peak indicated the presence of gold mineralization. Further work will be required to determine if minable reserves exist on the property. The Thunder Mountain project was a joint venture between Coeur d'Alene, Thunder Mountain Gold Inc. of Spokane, WA, and Phillips Petroleum Co.

To the west of Thunder Mountain, near Stibnite, gold recovery operations at the West End gold mine of TRV Minerals Corp. of Vancouver, and Superior Oil Co., a subsidiary of Mobil Oil Corp., were reportedly suspended during the 1985 operating season.

In the Yankee Fork mining district of Custer County, U.S. Antimony Corp. reportedly continued recovering gold and silver from three underground mines, an open pit, and a variety of old mine dumps dating from 1890 to 1910.

A number of small placer mining operations were reported to have been active along various Idaho waterways. Several seasonal operations were reportedly carried out along Prichard Creek and its tributaries near the old town of Murray, north of Wallace, in Shoshone County. Regulations of recreational and commercial placering operations continued to be a topic of concern in many areas of the State.

Preproduction permitting and production activities and exploration continued in many of Idaho's old mining districts. Exploration to locate and develop minable gold reserves was reportedly conducted by Concert Resources Inc. and Ican Resources Ltd. on their respective Blue Dog and Almaden properties in southwestern Idaho. Geodome Resources Ltd. of Hailey, ID, was reportedly nearing an early 1986 startup at its Sunbeam gold mine near Stanley in Custer County. Northwest of Stanley, Kellogg-based Golden Maple Mining and Leaching Co. was reported to be planning to reopen the old Valley Creek Mine as a small open pit, heap-leaching operation. Nevex Gold Inc. of Bellevue, WA, was reported to have been conducting a drilling program at its Robinson-Dike claims about 2 miles south of Dixie in Idaho County. At yearend, Liberty Bell Mines had reportedly purchased a relatively new flotation process mill from the Ensearch Exploration Inc.'s operations in Alaska; the mill was to be transported from Alaska to Liberty Bell's Monte Cristo claims in the Old Buffalo Hump mining district of Idaho County.

**Montana.**—Although the number of mining claims staked in Montana declined for the second consecutive year, there was a noticeable surge in exploration activity for precious metals on existing claims.

Placer U.S. Inc.'s Golden Sunlight Mine, east of Whitehall, the State's largest gold producer, produced 96,000 ounces of gold. Moderately increased mill throughput offset a lower average ore grade. Work continued on improvements to the mill circuit and expansion of the tailings system. Stripping of the stage II pit was under way in preparation for production in 1986.

Pegasus Gold Inc., of Spokane, WA, the second largest producer in the State, was actively engaged with several properties. At its Zortman-Landusky Mine, in the Little Rocky Mountains of Phillips County, Pegasus placed its new 7-million-ton heap-leach pad into production. Another pad, a so-called superpad, with a capacity to handle 20 million tons of ore, was under construction at yearend. Mining operations were confined to the Zortman Mine, on the western slopes of Ruby Gulch. No ore was mined at the Landusky pit because of ongoing studies there aimed at determining the optimal utilization of substantial new ore reserves acquired during 1984.

In Jefferson County, south of Helena, construction and permitting work continued at the Montana Tunnels project by joint venture partners Centennial Minerals Ltd., of Vancouver, and U.S. Minerals Exploration Co. (USMX), of Arvada, CO. On September 11, Pegasus made a tender for all of Centennial's outstanding common shares, and was anticipating the acquisition of the company's remaining shares in the near future. Through the acquisition of Centennial and execution of an agreement with USMX, Pegasus planned to develop the Mountain Tunnels project, with production to commence in May 1987 at a planned rate of 12,500 tons of ore per day; planned production was estimated at 106,000 ounces of gold and 1.7 million ounces of silver, plus values in lead and zinc. In October, the Montana Hard-Rock Mining Board gave final approval to the project. Near yearend, Pegasus let $3.5 million worth of engineering and construction contracts, with work to begin in March 1986. Pegasus placed its Beal project, in Silver Bow County, on standby pending resolution of environmental issues and the return of more favorable gold prices.

Golden Maple of Kellogg, ID, continued seasonal open pit mining and leaching operations at the old Gilt Edge property in Fergus County. In addition to leaching virgin ore, Golden Maple reportedly planned to process about 500,000 tons of on-site mill tailings left from earlier milling operations. Also in Fergus County, Triad Investments Inc. continued development work and leaching at the Kendall Mine, north of Lewiston. In Jefferson County's Elkhorn District, the Mount Hagen heap-leaching operation began production, and further development drilling was started at the deposit. To the north near Marysville, in Lewis and Clark County, AMAX Inc. and Gulf Titanium Ltd. began production at the historic old Belmont gold mine. Pending further development and possible construction of a mill on-site, the ore was being shipped to the East Helena, MT, smelter of ASARCO Incorporated. The Uncle Sam gold mine of Buckeye Mines Inc., in Madison County, was reopened and some ore was shipped.

Placer mining continued to flourish in Montana with operations in western Montana districts being particularly active. Three medium-sized operations were begun on Indian Creek, in Broadwater County. Seasonal operations were active in Meagher, Silver Bow, and Beaverhead Counties, and several properties were undergoing development in various counties farther west.

Exploration and development efforts were continued at a number of properties. In Madison County, Winchester Gold Corp. continued exploration and development at the old B and H Pete and Joe Mine. In Park County, southeast of Gardiner, Homestake Mining and American Copper & Nickel Co. Inc., a subsidiary of Inco Ltd., continued underground drilling and bulk sampling at their Jardine Joint Venture property. Production was scheduled to begin by mid-1987. Three different companies reportedly conducted some exploration drilling for gold in eastern Park County. Gold Coin Mining Inc., formerly Midas Gold Inc., of Spokane, WA, continued exploration at the old Gold Coin Mine in Deer Lodge County. The objective of the 1985 program was to prepare tunnel access to the mineralized zones so that a complete development program from underground could be conducted in 1986. Highlights of Montana mineral developments during 1985 were presented in a State report.[9]

**Nevada.**—Every year Nevada increases its margin over other States as the Nation's premier gold-producing State. Production, through 1985, has increased for 6 consecutive years. Gold occurrences, from isolated pockets through large disseminated deposits bearing millions of ounces of gold, were reportedly under examination or development in every county of the State in 1985. Nearly a dozen new gold mines or expansions of existing mines occurred in Nevada during the year.

On September 20, Carlin Gold Mining Co.'s new $130 million Gold Quarry Mine and No. 2 mill were officially dedicated. The new Eureka County facilities, about 14 miles south of the company's No. 1 mill and 8 miles north of the town of Carlin, will contribute substantially to Carlin's overall gold production capacity as well as that of its parent company, Newmont Mining Corp. By 1986, Carlin was expected to have the capacity to produce more than 330,000 ounces of gold annually, an increase of more than 100% over the capacity in 1984. The Gold Quarry deposit, discovered in 1980, contains an estimated 8 million ounces of gold, the second largest gold reserve in the State. Processing ore from the Gold Quarry Mine and the existing Maggie Creek Mine, both open pit operations, the new 2,500,000-ton-per-year No. 2 carbon-in-pulp mill will produce about 170,000 ounces of gold per year. Heap-leach pads adjacent to the mill will recover an estimated additional 35,000 ounces of gold per year.

In September, Newmont announced that exploration efforts by Carlin had resulted in the discovery of a new gold deposit about 3 miles from the Carlin Mine. The new deposit, designated as the "Genesis deposit," was expected to add about 5 million ounces of gold to the company's overall reserves of about 12 million ounces in the Carlin District. In addition to the Carlin, Gold Quarry, and Maggie Creek Mines, the company mined gold ore at its Blue Star and Bootstrap Mines.

In Humboldt County, northeast of Winnemucca, Pinson Mining Co., operator of the Pinson Mine, announced that testing and evaluation of the new Mag Zone, discovered about 0.5 mile from the Pinson mill in 1984, had resulted in the addition of about 3.1 million tons of milling-grade ore to the mine's reserves. Evaluation of another 1984 discovery, the CX Zone, immediately northeast of the Pinson open pit, was expected to add nearly 500,000 tons of reserves amenable to heap leaching and milling. Pinson Mining was owned by joint venture partners Lacana Gold Inc., Rayrock Mines Inc., United Siscoe Mines Inc., and private investors; effective December 31, United Siscoe sold its 26.25% interest in the partnership to American Barrick Resources Corp. Lacana Gold, a 70%-owned subsidiary of Lacana Mining Corp., of Toronto, Ontario, Canada, announced that feasibility studies on its new 51%-owned Santa Fe property in Mineral County were nearly complete and that exploration delineating 6 to 7 million tons of open pit oxide reserves had been completed. The company said, however, that a gold price of about $400 per ounce would be required to warrant proceeding to production. Lacana was also the owner and operator of the new Relief Canyon gold mine, which was opened in late 1984, east of Lovelock in Pershing County; however, owing to poor gold recovery, operations at Relief Canyon were suspended at yearend 1985. The company is also a partner in the Dee Mine in Elko County, opened concurrently with Relief Canyon. At yearend, the Dee mill was reported to be running at 950 tons per day, well in excess of its design capacity.

Freeport-McMoRan Gold Co. (FMG), a wholly owned subsidiary of Freeport McMoRan Inc., reported increases over that of 1984 in mine and mill production at its Enfield Bell (Jerritt Canyon) Mine of 20% and 6%, respectively. Total mill production for the year was 255,300 ounces, 12,000 ounces more than that of 1984. Two separate open pits, the upper North Generator ore body and the Second Cut of Marlboro Canyon, were being mined at the Elko County property, a joint venture with FMC Gold Corp. Prestripping of the West Generator ore body was scheduled to begin on a limited basis in 1986. Construction of a new millsite heap-leaching facility was begun in the third quarter of 1985, and leaching was expected to begin in 1986. The company was actively and successfully involved in exploration during the year; in the Jerritt Canyon joint venture area, six apparently viable or "advanced projects" underwent further evaluation, while two advanced projects, the Big Springs project north of the joint venture area and the Manhattan project to the south in Nye County, also underwent further scrutiny. Two other properties, the Burns Basin and Mill Creek properties, both in the joint venture area, were deemed to be commercially viable projects. In June, FMG became a publicly traded company; later in the year, the company officially opened its new international exploration headquarters in Reno, and exploration offices were subsequently opened in Vancouver, British Columbia, Canada, and Anchorage, AK.

At Battle Mountain in Lander County, Battle Mountain Gold Co., in November, completed a year of mining at its new Fortitude gold and silver mine and in the process exposed the higher grade core of the ore body; mining of the core area was expected to substantially reduce production costs. Battle Mountain Gold was established in August following its release to shareholders from its former parent, Pennzoil Corp.

Gold production at the Round Mountain Mine in Nye County, reportedly the world's largest heap-leaching operation, increased about 20,000 ounces in 1985 to about 140,000 ounces, reflecting both a 32% expansion of leaching capacity and the leaching of lean ore stockpiled in prior years. Reclassification of extensive mineralization not previously included in the mine's ore reserves resulted in a doubling of reserves to about 4.1 million ounces of contained gold. The Round Mountain operation is a joint venture between Echo Bay Inc. (50% interest), Homestake Mining (25%), and Case, Pomeroy and Co. (25%).

A number of relatively small gold mines began producing during 1985. Some of those reportedly beginning production were Pacific Silver Corp.'s underground gold, silver, and copper Buckskin Mine west of Yerington in Mason County; the Little Bald Mountain Joint Venture heap-leaching operation in White Pine County; Silver State Mining's Tonkin Springs heap-leaching project in Eureka County; Nevex Gold's Haywood-Santiago heap-leaching project near Virginia City; the Sumich joint venture and underground operation in Lander County; and Electra Northwest Resources Ltd.'s Aurora project, a heap-leaching operation in Mineral County.

Construction was begun or authorized to begin at numerous deposits where exploration and feasibility studies had been proceeding over the past few years. These include AMAX's Sleeper project in Humboldt County; Silver King Mines Inc. and Pacific Silver's Star Pointer near Ely; Coeur d'Alene's project at Rochester; FMC Corp.'s Paradise Peak project near Gabbs in Nye County; Atlas Corp.'s Gold Bar property in Eureka County; the Florida Canyon project of Pegasus near Winnemucca; and the Top deposit of Placer U.S. in northeastern White Pine County.

Depressed gold and silver prices led to the closure of several mines including the Gooseberry Mine and United Mining Corp.'s Comstock operations, both in Storey County.

Periodical news media reports dealing with mineral exploration were rarely without reports on new developments in Nevada. In addition to reports about ongoing projects and discoveries associated with some of the operating mines discussed above, nearly 36 exploration projects were reported under way; many more smaller operations were undoubtedly in progress. One of the most notable discoveries reported during the year was Gold Fields' Chimney Creek Prospect, discovered near Golconda in Humboldt County; Gold Fields estimated that the new disseminated deposit contains 2 million ounces of gold.

**New Mexico.**—Citing impending depletion of economic ore reserves and increased mining costs associated with deeper ore and greater waste removal costs, Gold Fields Operating Co., a wholly owned subsidiary of Consolidated Gold Fields of London, United Kingdom, announced in mid-1985 that its Ortiz Mine at Cerrillos would cease production in 1986. The open pit, heap-leaching operation had been in production since February 1980.

A number of small surface and underground gold mines were active throughout the State during 1985.

**Oregon.**—Developments in Oregon were confined to exploration or intermittent production from small lode and placer operations. Of the 24 mining operations active in Oregon during 1985, 12 were placer mines. Most of these mines or mining areas were in Baker, Douglas, Grant, Jackson, and Josephine Counties; only a few produced over 50 ounces of gold. The most productive areas were in Baker and Grant Counties of eastern Oregon along Pine Creek near Hereford, on Clark Creek on the upper Burnt River, and on Boulder Creek near Granite.

Small seasonal lode-mine operations were again reported from the Pyx Mine in Grant County and from the Thomason Mine in Baker County. Closure of Silver King Mines' Iron Dyke Mine in Baker County during 1984 and only sporadic work there during 1985 sharply reduced the State's lode gold production.

According to a State review of the year's mining and exploration activities,[10] exploration and development activity in 1985 generally declined from 1984 levels, with the industry apparently continuing to shift its interests away from metallic minerals and toward nonmetallic minerals. Properties reported to have undergone some manner of exploration, from rudimentary investigation through drilling or rehabilitation of old workings, included the Bald Mountain-Ibex, Bear Creek Buttes, Cable Cove, Castle Rock, Coyote Hills, Dixie Meadows, Fall Creek Copper, Flagstaff, Flagstaff Butte, Goff, Gold Bug, Gold Note, John Hall, Little Baldy, Meadow Lake, Miller Mountain, Quartz Mountain, Red Butte, Rejax, Sunday Hill, Susanville, and Turner-Albright. Nearly one-third of the properties under investigation were in Baker and Grant Counties.

**South Dakota.**—Gold developments for the year were centered about the town of Lead, in Lawrence County in the Black Hills area of the State. Gold production at the Homestake Mine, the Nation's largest gold mine, increased to 343,103 ounces in 1985, 16% greater than its 1984 production of 295,941 ounces. The average cost of production decreased to $294 per ounce, compared with $324 per ounce in 1984. The lower costs not only reflected results from a cost-cutting program begun in early 1985, but also from record mine efficiency and mill throughput; the quantity of ore milled was the highest in the mine's century of existence. The average grade of ore from the underground operation was 0.174 ounce per ton, essentially the same as that of 1984. Mining and exploration work in 1985 continued below the 6,800-foot level, the deepest current working level. Major development work was continued on three deeper levels, extending to 8,000 feet below the surface.

Testing of the Terraville or open pit area, site of the original strike more than a century ago, confirmed earlier reserve estimates. A decision was thus made to put the area into full-scale production by 1987. Homestake also began a program to place a greater emphasis on exploration both at the mine and in the surrounding Black Hills

District and to evaluate new exploration targets generated through the development of new geologic models and structural interpretations.

Near Trojan, west of Lead, in the Bald Mountain mining district, Wharf Resources (USA) Inc. of Helena, MT, continued open pit, heap-leaching operations at its Annie Creek gold mine, and by yearend, Wharf had applied for the final round of permits required to expand the operation northeastward onto its Foley Ridge area of the project. Exploration and testing had been under way at Foley Ridge for several years. Subsequent preliminary investigation of the adjoining Portland property indicated the existence of a strongly mineralized near-surface deposit. Wharf, in partnership with Homestake, controls about 3,000 acres of mineral rights in the area.

To the north, at Richmond Hill in the Carbonate area, St. Joe Gold Corp. drilled 71 exploratory holes and detected the presence of disseminated gold, in addition to gold mineralization exposed at the surface. Preliminary metallurgical tests indicated that the oxidized ore would be suitable for heap leaching. Further exploration in the area was planned.

In the Ruby Basin District, about 2.5 miles southwest of Lead, Moruya Gold Mines of North America Inc., a subsidiary of Moruya Gold Mines (1983) NL, of Sydney, Australia, in a joint venture with Coin Lake Gold Mines Ltd., of Toronto, Ontario, Canada, acquired, from Anaconda Minerals Co., a large block of claims known collectively as the Golden Reward project. By yearend, Moruya had reportedly completed the first stage of a drilling program aimed at determining the gold potential of the old Golden Reward and other former producing properties within the claims area.

On Strawberry Hill, above Galena, 4 miles southeast of Lead, Gilt Edge Inc., a subsidiary of Lacana Gold, continued development on its Gilt Edge property. A production decision reportedly was to depend upon State permitting requirements and higher gold prices.

**Utah.**—Kennecott closed its Bingham Canyon Mine near Salt Lake City, at the end of March, owing to continuing financial losses. For many years, the Bingham Canyon open pit copper mine had been one of the Nation's leading byproduct gold producers. In December, Kennecott's parent company, the Standard Oil Co. of Ohio, a 55%-owned subsidiary of British Petroleum, announced a $400 million, 3-year project aimed at modernizing Kennecott's Utah Copper Div., operator of the mine.

In May, Texaco Inc. announced the sale of its Getty Gold Mine Co. to a wholly owned U.S. subsidiary of Barrick Resources of Toronto, Ontario, Canada. Getty operates the Mercur open pit gold mine and mill at Toole. Annual production at the 80,000-ounce-per-year facility will reportedly be expanded by about 15,000 ounces through the addition of heap-leaching capacity. With the closure of the Bingham Canyon Mine, the Mercur Mine became the largest gold producer in Utah.

**Washington.**—In September, Asamera Minerals (U.S.) Inc. and its partner Breakwater Resources Ltd., both subsidiaries of Canadian companies, dedicated the Cannon Mine on the outskirts of Wenatchee in Chelan County. The Cannon was developed as an underground mine. Overhand cut and fill was employed as the principal mining method, combined with a 4,000-ton-per-day underground crusher and a trackless system for ore haulage. The new 2,000-ton-per-day flotation mill produced a gold-silver-bearing concentrate that was shipped to smelters in Western Europe and Japan. At full production, the mine was expected to yield between 160,000 and 180,000 ounces of gold per year, plus about 70,000 ounces of silver per year. In October, the partners announced that they had acquired all of the property interests held in the immediate area of the mine by Tenneco Inc. and United Mining.

The flurry of exploration activity in Chelan County, touched off by Asamera-Breakwater's 1982 discovery, abated in 1985, with only 11 companies reporting work, compared with 27 reporting during 1984.

The second principal development in the State was Hecla Mining Co.'s announcement early in the year that exploration and development work at its Knob Hill Mine at Republic, in Ferry County, had resulted in the discovery of additional ore. The company was then able to postpone for perhaps 5 years its earlier decision to close the mine, in operation almost continuously since the early 1900's. Development of the two new gold and silver veins, the Golden Promise I and II, was proceeding at yearend from an exploration drift on the mine's 11th level. Total gold production for the year was 39,192 ounces, up 72% from that of 1984. Elsewhere in Ferry County, at the South

Penn property, 14 miles north of Republic, the mine's operator, Glamis Gold of Vancouver, conducted bulk leaching tests on finely crushed agglomerated material from its property. Vulcan Mountain Inc. continued heap leaching at its Gold Dike Mine and had expanded operations on the adjoining Gold Hill property before work was stopped for the winter. Exploration was conducted at several other Ferry County properties during the year.

To the west in Okanogan County, exploration and/or drilling was carried out on Crown Resource Corp.'s Key property, Sunshine Valley Minerals Inc.'s Billy Goat property, Keystone Gold Inc.'s Crystal Butte and Grey Eagle properties, and at several other properties in the county. Cordilleran Development Inc. continued geological mapping and heap-leaching operations at its Minnie Mine near Twisp.

Other gold mining operations reported to be active were CSS Management Corp.'s Apex and Damon properties near Skykomish in King County, and Younguist Mine Development and Consultation Inc.'s Wind River Mine near Carson, in Skamania County.

Gold and silver were reportedly the targets of 70% of the companies exploring in the State, with Stevens County the most active area as far as base and precious metals exploration was concerned. Mining and exploration activities in the State during the year were summarized by the Washington State Department of Natural Resources.[11]

**Other States.**—Two new gold mines opened east of the Mississippi River in 1985, and exploration of known or potential gold-bearing areas from Alabama north to Maine and west to Wisconsin and Minnesota continued, although at a somewhat subdued pace compared with the pace of the previous 3 or 4 years.

On October 18, Callahan Mining dedicated its new Ropes gold mine near Ishpeming in Marquette County, MI. The newly rehabilitated underground mine, closed since 1941, was expected to yield up to about 60,000 ounces per year following mill tuneup and normalization of mining operations near mid-1986. Mining started in August 1985, between the 800- and 900-foot levels where reserves are of lower grade than the mine's average of about 0.1 ounce per ton. Ore was hauled 16 miles to the mine's newly converted 2,000-ton-per-day mill at Humboldt. The first bar of gold doré recovered from the operation was poured on September 20. Callahan Mining was maintaining its exploration efforts to locate additional gold deposits in the Ishpeming area.

Near Kershaw in Lancaster County, SC, Piedmont Mining Co. brought the old Haile Mine back into production as an open pit, heap-leaching operation. Mining operations at the former underground producer, first opened in 1829, began in January 1985, and the first bar of production gold was poured in March. At full production, the mine was expected to produce 10,000 to 12,000 ounces per year. Piedmont was a privately held company based in Charlotte, NC. Meanwhile, near Ridgeway in Fairfield County, adjoining Lancaster County to the southwest, Amselco Minerals of Denver, CO, a subsidiary of British Petroleum, following several years of exploration in Fairfield and adjoining Richland County, announced in early 1986 that it had discovered two potentially viable gold deposits in Fairfield County about 1 mile apart near the Richland County line.

Small intermittent gold-placering operations were conducted in various gold-bearing areas of the South. A number of companies and individuals were actively exploring for gold in the old gold mining areas of North Carolina, and a few continued to investigate prospects in Alabama, Georgia, and Virginia. Corporate activity, however, generally declined during the second half of the year.

The University of Connecticut discovered traces of gold in several quartz samples collected in a study area near Cobalt in the Meshomasic State Forest. Although gold claims have in the past been staked in various areas of Connecticut, the discoveries near Cobalt were reportedly the State's first gold discoveries to be properly documented.

In Maine, exploration by Freeport-McMoRan at its Bald Mountain copper and precious metals deposit in Aroostock County was discontinued in January. Getty Mining Co.'s exploration at the Mount Chase base and precious metals deposit in northern Penobscot County apparently was suspended while Getty underwent a change in ownership. Noranda Exploration Co. reportedly continued its base and precious metals exploration programs in Franklin and Somerset Counties, while Scintilore Explorations Ltd., of Toronto, Ontario, Canada, reportedly conducted exploration at its Big Hill Prospect, 14 miles from Eastport in

Washington County.

In Minnesota during October, the State Department of Natural Resources (DNR) held its ninth sale of State copper, nickel, and associated minerals leases. Leases covering about 735,000 acres of State-owned mineral rights were offered. Much of the interest was reportedly focused on the potential for possible gold deposits in the greenstone belts in an area south of Ranier in northeastern Koochiching County and in the area bounded by Virginia, Eveleth, and Gilbert in central St. Louis County. Lease lands were also sought in Aitken, Itasca, Lake, and Pine Counties. The Kerr-McGee Corp. of Oklahoma was reportedly the successful bidder for the Koochiching and central St. Louis County offerings. Other companies also reportedly showing an interest in the lease areas included Boise Cascade's Normin Mining Co., Burlington Northern's Meridian Minerals Co., Lehmann Exploration Management Inc. of Minneapolis, and the American Shield Co. of Duluth. Seventeen companies were reportedly successful in their bidding efforts. Most of the companies were apparently interested in the potential for gold and other precious metals on the lands offered. To encourage interest in the leasable lands program, the DNR has reportedly improved its aeromagnetic mapping coverage and stepped up an effort to reexamine its collection of rock and core samples derived from earlier exploration on State lands. Several companies were also interested in exploring for gold on privately held lands, especially in northern Minnesota.

Near Rhinelander, WI, near Exxon Minerals Co.'s base metal deposit at Crandon, Mineralco, an Illinois company, and InteResources Inc. of San Antonio, TX, were reportedly investigating a possible disseminated gold prospect at Hickson Lake.

**Table 4.—Mine production of gold in the United States, by month**

(Troy ounces)

| Month | 1981 | 1982 | 1983[r] | 1984[r] | 1985 |
|---|---|---|---|---|---|
| January | 98,887 | 106,956 | 134,435 | 140,586 | 178,287 |
| February | 93,385 | 109,407 | 131,636 | 144,945 | 178,869 |
| March | 115,200 | 138,066 | 153,808 | 174,242 | 208,434 |
| April | 110,366 | 136,674 | 162,224 | 166,908 | 187,869 |
| May | 108,291 | 143,212 | 179,950 | 183,068 | 197,065 |
| June | 119,676 | 116,925 | 178,929 | 195,337 | 194,887 |
| July | 126,675 | 114,845 | 179,521 | 186,620 | 203,028 |
| August | 125,505 | 114,538 | 192,095 | 183,123 | 204,550 |
| September | 124,629 | 109,024 | 189,237 | 178,483 | 240,159 |
| October | 123,201 | 127,928 | 183,524 | 186,413 | 224,838 |
| November | 119,386 | 127,843 | 165,903 | 174,313 | 230,361 |
| December | 113,960 | 120,268 | 151,264 | 170,577 | 227,089 |
| Total | 1,379,161 | 1,465,686 | 2,002,526 | 2,084,615 | 2,475,436 |

[r] Revised.

### Table 5.—Twenty-five leading gold-producing mines in the United States in 1985, in order of output

| Rank | Mine | County and State | Operator | Source of gold |
|---|---|---|---|---|
| 1 | Homestake | Lawrence, SD | Homestake Mining Co | Gold ore. |
| 2 | Enfield Bell (Jerritt Canyon) | Elko, NV | Freeport Gold Co | Do. |
| 3 | Battle Mountain | Lander, NV | Battle Mountain Gold Co | Do. |
| 4 | Carlin & Maggie Creek Pit | Eureka, NV | Carlin Gold Mining Co | Do. |
| 5 | Round Mountain | Nye, NV | Round Mountain Gold Corp | Do. |
| 6 | Cannon | Chelan, WA | Asamera Minerals (U.S.) Inc | Do. |
| 7 | Golden Sunlight | Jefferson, MT | Golden Sunlight Mines Inc | Do. |
| 8 | Mecur | Tooele, UT | Barrick Mercur Gold Mines Inc | Do. |
| 9 | McLaughlin | Napa, CA | Homestake Mining Co | Do. |
| 10 | Pinson | Humboldt, NV | Pinson Mining Co | Do. |
| 11 | Zortman-Landusky | Phillips, MT | Pegasus Gold Inc | Do. |
| 12 | Cortez | Lander, NV | Cortez Gold Mines | Do. |
| 13 | Borealis Project | Mineral, NV | Tenneco Minerals Co | Do. |
| 14 | Dee | Elko, NV | Dee Gold Mining Co | Do. |
| 15 | Alligator Ridge | White Pine, NV | Amselco Minerals Inc | Do. |
| 16 | Grey Eagle | Siskiyou, CA | Noranda Grey Eagle Mines Inc | Do. |
| 17 | Gold Strike | Eureka, NV | Western States Minerals Corp | Do. |
| 18 | Ortiz | Santa Fe, NM | Gold Fields Operating Co | Do. |
| 19 | Delamar | Owyhee, ID | Nerco Minerals Co | Do. |
| 20 | Manhattan | Nye, NV | Tenneco Minerals Co | Do. |
| 21 | Picacho | Imperial, CA | Chemgold Inc | Do. |
| 22 | Valdez Creek | Cook Inlet, Susitna, AK | Valdez Creek Mining Co. Inc | Placer. |
| 23 | Northumberland | Nye, NV | Cyprus-Northumberland Mining Co | Gold ore. |
| 24 | Trixie | Utah, UT | Sunshine Mining Co | Do. |
| 25 | Morenci | Greenlee, AZ | Phelps Dodge Corp | Copper ore. |

## Table 6.—Gold produced in the United States, by State, type of mine, and class of ore

| Year and State | Placer (troy ounces of gold) | Lode | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Gold ore | | Gold-silver ore | | Silver ore | | Copper ore | |
| | | Short tons | Troy ounces of gold | Short tons | Troy ounces of gold | Short tons | Troy ounces of gold | Short tons | Troy ounces of gold |
| 1981 | 28,927 | 12,728,940 | 921,930 | 1,040,856 | 40,514 | 4,408,806 | 15,254 | 264,347,788 | 352,768 |
| 1982 | 38,466 | 17,918,046 | 1,124,225 | 1,213,247 | 37,697 | 5,318,490 | 13,539 | [r]150,095,844 | 233,093 |
| 1983 | 53,887 | [r]24,141,617 | [r]1,593,406 | 1,124,556 | [r]43,445 | [r]7,512,261 | [r]35,057 | [r]137,668,016 | 258,222 |
| 1984 | [r]37,597 | [r]30,497,262 | [r]1,736,998 | [r]1,587,850 | [r]55,382 | 4,380,945 | 25,785 | [r]132,899,873 | [r]198,729 |
| 1985: | | | | | | | | | |
| Alaska | W | W | W | -- | -- | -- | -- | -- | -- |
| Arizona | W | -- | -- | W | W | -- | -- | 126,290,430 | 46,056 |
| California | 3,966 | W | W | W | W | -- | -- | -- | -- |
| Colorado | -- | 811,529 | 27,067 | -- | -- | W | W | -- | -- |
| Idaho | -- | 50,638 | 2,977 | W | W | 949,183 | 11,032 | -- | -- |
| Michigan | -- | W | W | -- | -- | -- | -- | -- | -- |
| Montana | 1,123 | 7,528,000 | 158,556 | W | W | 40,832 | 158 | 2,842,971 | W |
| Nevada | W | 19,808,568 | 1,246,290 | W | W | W | W | -- | -- |
| New Mexico | -- | 914,946 | 36,017 | 2,527 | 585 | W | W | W | W |
| Oregon | W | W | W | -- | -- | -- | -- | -- | -- |
| South Carolina | -- | W | W | -- | -- | -- | -- | -- | -- |
| South Dakota | -- | 2,545,704 | 356,103 | -- | -- | -- | -- | -- | -- |
| Utah | -- | 1,243,782 | 97,233 | -- | -- | -- | -- | W | W |
| Washington | -- | W | W | -- | -- | -- | -- | -- | -- |
| Total[1] | 50,587 | 35,908,918 | 2,241,836 | 1,043,854 | 41,801 | 3,836,130 | 31,288 | 149,464,862 | 74,633 |
| Percent of total gold | 2 | XX | 91 | XX | 2 | XX | 1 | XX | 3 |

| Year and State | Lode | | | | | | Total[1] | |
|---|---|---|---|---|---|---|---|---|
| | Lead and zinc ores | | Copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores | | Old tailings, etc. | | | |
| | Short tons | Troy ounces of gold | Short tons | Troy ounces of gold | Short tons | Troy ounces of gold | Short tons | Troy ounces of gold |
| 1981 | 638 | 30 | 3,152,611 | 11,582 | 361,588 | [2]8,156 | 286,041,227 | 1,379,161 |
| 1982 | -- | -- | (3) | (3) | [4]646,084 | [5]18,666 | [r]175,191,711 | 1,465,686 |
| 1983 | -- | -- | (3) | (3) | [4]858,749 | [6]18,509 | [r]171,305,199 | [r]2,002,526 |
| 1984 | (3) | (3) | (3) | (3) | [7]472,359 | [8]30,124 | [r]169,838,289 | [r]2,084,615 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1985: | | | | | | | | |
| Alaska | -- | -- | -- | -- | -- | -- | W | 44,733 |
| Arizona | -- | -- | -- | -- | W | W | 126,408,664 | 52,053 |
| California | -- | -- | -- | -- | -- | -- | 2,492,622 | 165,101 |
| Colorado | -- | -- | W | W | -- | -- | 1,033,994 | 43,301 |
| Idaho | -- | -- | -- | -- | W | W | 5,583,063 | 44,306 |
| Michigan | -- | -- | -- | -- | -- | -- | W | W |
| Montana | -- | -- | -- | -- | W | W | 10,412,118 | 160,262 |
| Nevada | -- | -- | -- | -- | W | W | 22,833,817 | 1,276,114 |
| New Mexico | -- | -- | -- | -- | 35 | 344 | 18,605,044 | 45,045 |
| Oregon | -- | -- | -- | -- | -- | -- | W | W |
| South Carolina | -- | -- | -- | -- | -- | -- | W | W |
| South Dakota | -- | -- | -- | -- | -- | -- | 2,545,704 | 356,108 |
| Utah | -- | -- | -- | -- | W | W | 3,900,367 | 185,489 |
| Washington | -- | -- | -- | -- | -- | -- | W | W |
| Total[1] | -- | -- | (3) | (3) | [4]4,476,684 | [5]35,291 | 194,730,448 | 2,475,436 |
| Percent of total gold | XX | -- | XX | (3) | XX | 1 | XX | 100 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.

[1] Data may not add to totals shown because of items withheld to avoid disclosing company proprietary data.

[2] Includes gold recovered from tungsten ore.

[3] Included with "Old tailings, etc."

[4] Includes lead-zinc ores.

[5] Includes gold recovered from lead-zinc and molybdenum ores.

[6] Includes gold recovered from lead-zinc ores.

[7] Includes lead and lead-zinc ores.

[8] Includes gold recovered from lead ore, lead-zinc ores, and molybdenum ore.

## Table 7.—Lode gold produced in the United States, by State

| Year and State | Amalgamation | | Cyanidation | | Smelting of concentrates | | | Smelting of ore | | Total ore processed[1] (short tons) | Total gold recovered (troy ounces) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ore treated (short tons) | Gold recovered (troy ounces) | Ore treated (short tons) | Gold recovered (troy ounces) | Ore concentrated (short tons) | Concentrates smelted (short tons) | Gold recovered (troy ounces) | Ore smelted (short tons) | Gold recovered (troy ounces) | | |
| 1981 | 186,790 | 14,945 | 15,899,228 | 912,742 | $^{r}$269,468,293 | 6,213,345 | 404,750 | 486,916 | $^{3}$17,859 | $^{r}$286,041,227 | $^{3}$1,350,296 |
| 1982 | $^{r}$140,196 | 25,416 | $^{r}$19,901,354 | 1,101,721 | $^{r}$154,933,339 | $^{r}$3,245,464 | 290,023 | $^{r}$216,822 | $^{r}$10,060 | $^{r}$175,191,711 | $^{r}$1,427,220 |
| 1983 | $^{r}$137,658 | 24,689 | $^{r}$28,415,818 | $^{r}$1,631,608 | $^{r}$142,546,432 | $^{r}$3,044,307 | $^{r}$306,609 | $^{r}$205,291 | $^{r}$ $^{3}$9,996 | $^{r}$171,305,199 | $^{r}$ $^{3}$1,972,902 |
| 1984 | $^{r}$124,983 | 23,274 | $^{r}$34,902,191 | $^{r}$1,752,492 | $^{r}$134,735,157 | $^{r}$3,605,791 | $^{r}$257,238 | 75,958 | $^{3}$14,214 | $^{r}$169,838,289 | $^{r}$ $^{3}$2,047,218 |
| 1985: | | | | | | | | | | | |
| Alaska | -- | -- | W | W | -- | -- | -- | -- | -- | W | W |
| Arizona | -- | -- | -- | -- | 126,215,580 | 3,019,588 | 46,056 | 193,084 | $^{3}$5,997 | 126,408,664 | $^{3}$52,053 |
| California | W | W | W | W | W | W | W | -- | -- | 2,492,622 | 161,135 |
| Colorado | W | W | W | W | 250,767 | 38,028 | 18,151 | 500 | 6 | 1,033,994 | 43,301 |
| Idaho | -- | -- | W | W | 4,712,523 | 74,217 | 11,125 | W | W | 5,583,063 | 44,306 |
| Michigan | -- | -- | W | W | -- | -- | -- | -- | -- | W | W |
| Montana | -- | -- | 7,527,700 | 157,906 | 2,883,803 | 39,293 | 418 | 610 | 815 | 10,412,113 | 159,139 |
| Nevada | -- | -- | 22,833,662 | 1,271,549 | $^{2}$80 | 1,556 | 25 | 75 | $^{3}$4,540 | 22,833,817 | $^{2}$1,276,114 |
| New Mexico | -- | -- | 914,946 | 36,017 | W | W | W | W | W | 18,605,044 | 45,045 |
| Oregon | W | W | -- | -- | -- | -- | -- | W | W | W | W |
| South Carolina | -- | -- | W | W | -- | -- | -- | -- | -- | W | W |
| South Dakota | -- | -- | 2,545,704 | 356,103 | -- | -- | -- | -- | -- | 2,545,704 | 356,103 |
| Utah | -- | -- | 1,352,969 | 108,313 | W | W | W | W | W | 3,900,367 | 135,489 |
| Washington | -- | -- | W | W | W | W | W | -- | -- | W | W |
| Total | 20,812 | 3,741 | 39,602,183 | 2,159,731 | 154,886,138 | 3,220,471 | 231,706 | 221,315 | $^{3}$34,179 | 194,730,448 | $^{3}$2,429,357 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Includes old tailings and some nongold-bearing ores not separable, in amounts ranging from 0.15% to 0.25% of the totals for the year listed.

[2] Includes some placer production to avoid disclosing company proprietary data.

[3] Excludes molybdenum and tungsten ores from which gold was recovered as a byproduct and ores leached for recovery of copper.

## Table 8.—Gold produced in the United States by cyanidation[1]

| Year | Extraction in vats, tanks, and closed containers[2] |  | Leaching in open heaps or dumps[3] |  |
|---|---|---|---|---|
|  | Ore treated (short tons) | Gold recovered[4] (troy ounces) | Ore treated (short tons) | Gold recovered (troy ounces) |
| 1981 | 7,023,836 | 648,334 | 8,875,392 | 264,408 |
| 1982 | 7,616,036 | 710,688 | 12,294,232 | 391,033 |
| 1983 | 11,317,285 | 1,086,205 | [r]17,098,533 | [r]545,408 |
| 1984[r] | 13,503,143 | 1,165,983 | 21,399,048 | 586,509 |
| 1985 | 20,542,717 | 1,626,751 | 19,059,466 | 532,980 |

[r] Revised.

[1] May include small quantities recovered by leaching with thiourea, by bioextraction, and by proprietary processes.

[2] Includes autoclaves.

[3] May include tailings and waste ore dumps.

[4] May include small quantities recovered by gravity methods.

## Table 9.—Gold produced at placer mines in the United States, by method of recovery[1]

| Method of recovery | Mines producing | Washing plants | Material washed (thousand cubic yards) | Gold recoverable |  |  |
|---|---|---|---|---|---|---|
|  |  |  |  | Quantity (thousand troy ounces) | Value (thousands) | Average value per cubic yard |
| Bucketline dredging: |  |  |  |  |  |  |
| 1981 | 3 | 5 | [2]2,190 | 15 | $6,731 | $3.073 |
| 1982 | 6 | 8 | 4,702 | 22 | 8,130 | 1.729 |
| 1983 | 3 | 4 | 4,785 | 30 | 12,512 | 2.615 |
| 1984[r] | 2 | 3 | 4,840 | 29 | 10,387 | 2.147 |
| 1985 | 2 | 3 | 826 | 9 | 2,971 | 3.597 |
| Dragline dredging: |  |  |  |  |  |  |
| 1981 | 1 | 7 | [3]30 | [4]6 | 1,200 | 13.023 |
| 1982 | 3 | 14 | [3]29 | [4]3 | 1,168 | 18.960 |
| 1983 | 2 | 13 | [3]110 | [4]3 | 1,333 | 3.481 |
| 1984 | 4 | [r]13 | [3]126 | [4]4 | 1,593 | [r] [5]2.908 |
| 1985 | 3 | 14 | [3]156 | [4]4 | 1,348 | 2.224 |
| Hydraulicking: |  |  |  |  |  |  |
| 1981 | 7 | 7 | 113 | 1 | 526 | 4.678 |
| 1982 | 4 | 4 | 17 | ([6]) | 139 | 8.026 |
| 1983 | 1 | 1 | 3 | ([6]) | 117 | 43.342 |
| 1984 | 1 | 1 | 28 | ([6]) | 90 | 3.220 |
| 1985 | -- | -- | -- | -- | -- | -- |
| Nonfloating washing plants: |  |  |  |  |  |  |
| 1981 | 9 | 13 | [3]894 | [4]9 | 4,438 | 4.869 |
| 1982 | 10 | 11 | 805 | 13 | 4,829 | 6.000 |
| 1983 | 6 | 6 | 961 | 18 | 7,450 | 7.750 |
| 1984 | 8 | 8 | [r]310 | 3 | 1,036 | [r]3.343 |
| 1985 | 6 | 6 | 959 | 31 | 9,690 | 10.102 |
| Underground placer, small-scale mechanical and hand methods, suction dredge: |  |  |  |  |  |  |
| 1981 | 6 | 7 | 108 | 1 | 401 | 3.728 |
| 1982 | 15 | 15 | 30 | ([6]) | 174 | 5.848 |
| 1983 | 23 | 24 | [3]167 | [4]3 | 1,437 | 7.831 |
| 1984 | 10 | 11 | [r]197 | 1 | 454 | [r]2.304 |
| 1985 | 19 | 19 | 621 | 6 | 2,061 | 3.320 |
| Total placers:[7] |  |  |  |  |  |  |
| 1981 | 26 | 39 | [2] [3]3,335 | [4]29 | 13,296 | [5]3.719 |
| 1982 | 38 | 52 | [3]5,584 | [4]38 | 14,460 | [5]2.475 |
| 1983 | 35 | 48 | [3]6,026 | [4]54 | 22,849 | [5]3.792 |
| 1984[r] | 25 | 36 | [3]5,501 | [4]38 | 13,560 | [5]2.242 |
| 1985 | 30 | 42 | [3]2,561 | [4]51 | 16,069 | [5]5.882 |

[r] Revised.

[1] Data are only for those mines that report annually on the Bureau of Mines voluntary survey; there are many more, usually smaller and less well-established operations, mainly in Alaska, that do not report.

[2] Does not include platinum-bearing material from which byproduct gold was recovered.

[3] Excludes tonnage of material treated at commercial sand and gravel operations recovering byproduct gold.

[4] Includes gold recovered at commercial sand and gravel operations.

[5] Gold recovered as a byproduct at sand and gravel operations is not used in calculating average value per cubic yard.

[6] Less than 1/2 unit.

[7] Data may not add to totals shown because of independent rounding.

### Table 10.—U.S. refinery production of gold

(Thousand troy ounces)

| Raw material | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Concentrates and ores: | | | | | |
| Domestic | 801 | 718 | 885 | [r]760 | 620 |
| Foreign | 4 | 1 | 7 | 4 | -- |
| Old scrap[1] | 1,610 | 1,444 | 1,380 | 1,310 | 1,215 |
| New scrap | 1,475 | 1,596 | [r]1,590 | [r]1,794 | 1,520 |
| Total[2] | 3,890 | 3,760 | [r]3,863 | [r]3,868 | 3,355 |

[r] Revised.

[1] Excludes upgrading of U.S. Government-owned gold (mostly coin gold) by the U.S. Assay Office, amounting to 2,476,628 ounces in 1981. Refining activity terminated in Sept. 1981.

[2] Data may not add to totals shown because of independent rounding.

## CONSUMPTION AND USES

Just over 3 million ounces of gold was consumed by domestic end-use industries in 1985, slightly less than that of 1984. Jewelry and the arts continued to be, as in years past, the principal end use, accounting for about 53% of overall consumption. Electronic products, specialty alloys, and aerospace applications absorbed about 34% of the total. Consumption in various dental applications increased slightly, accounting for nearly 13% of the total. Consumption in the fourth end-use category, small items for investment, continued to decline relative to earlier years, apparently in favor of other gold and nongold investment vehicles, and was negligible in 1985.

Sales of U.S. Department of the Treasury gold medallions and Olympic gold coins declined substantially, principally as a result of fulfillment of the minting requirements set forth in the enabling legislation.

Trading activity on the Nation's gold futures exchange markets declined for the third consecutive year, apparently to some extent as a result of the increasing popularity of trading in gold-based options, a declining rate of domestic currency inflation, and trading in more attractive investment opportunities in other markets, such as securities.

On July 10, the International Monetary Market in Chicago discontinued all gold futures trading activity. In October, members of Chicago's MidAmerica Commodity Exchange and the Chicago Board of Trade (CBOT) approved an affiliation agreement. The agreement called for the MidAmerica to remain a separate legal entity and a separate exchange and the CBOT to become the sole voting and equity member of the MidAmerica.

### Table 11.—U.S. consumption of gold,[1] by end use

(Thousand troy ounces)

| End use | 1981 | 1982[2] | 1983[2] | 1984[2] | 1985[2] |
|---|---|---|---|---|---|
| Jewelry and the arts: | | | | | |
| Karat gold | 1,420 | 1,638 | 1,410 | [r]1,466 | 1,418 |
| Fine gold for electroplating | 24 | 17 | 18 | 18 | 27 |
| Gold-filled and other | 286 | 301 | 237 | 225 | 198 |
| Total[3] | 1,730 | 1,954 | [r]1,666 | [r]1,709 | 1,643 |
| Dental | 314 | 358 | 360 | 363 | 394 |
| Industrial: | | | | | |
| Karat gold | 50 | 64 | 44 | 42 | 36 |
| Fine gold for electroplating | 528 | 389 | 344 | 415 | 326 |
| Gold-filled and other | 633 | 649 | 644 | 628 | 693 |
| Total[3] | 1,210 | 1,102 | 1,032 | 1,084 | 1,055 |
| Small items for investment[4] | 22 | 9 | 3 | 8 | 7 |
| Grand total[3] | 3,276 | 3,423 | 3,061 | [r]3,164 | 3,100 |

[r] Revised.

[1] Gold consumed in fabricated products only; does not include monetary bullion.

[2] Data may include estimates.

[3] Data may not add to totals shown because of independent rounding.

[4] Fabricated bars, medallions, coins, etc.

## STOCKS

**Official.**—Stocks of gold bullion, held by the Department of the Treasury, continued to decline slowly, reflecting, in part, material consumed to satisfy minting requirements of the Department's gold medallion and commemorative coin program.

Official gold reserves of the market economy countries, including stocks held by the International Monetary Fund (IMF) and the Bank for International Settlements, totaled 1.144 billion ounces at yearend, compared with 1.142 billion ounces at yearend 1984. IMF yearend stocks, 103.43 million ounces, were unchanged from stocks reported since 1980.

**Commercial.**—Stocks of refined gold held by industrial users at yearend were 16% lower than stocks on hand at the end of 1984. The sharpest decrease in inventories occurred during the first quarter, as users apparently began withdrawing material to meet anticipated demand later in the year. Yearend stocks of gold certified for delivery by the Commodity Exchange Inc., New York, the Nation's largest gold futures exchange, comprise nearly all U.S. futures exchange stocks; they declined about 9% from the yearend 1984 level.

### Table 12.—Yearend stocks of gold in the United States

(Thousand troy ounces)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Industry | 635 | 776 | [r]623 | [r]765 | 639 |
| Futures exchange | 2,449 | 2,303 | 2,530 | 2,359 | [1]2,110 |
| Department of the Treasury[2] | 264,116 | 264,046 | 263,406 | 262,814 | 262,672 |
| Earmarked gold[3] | 350,640 | 348,555 | 341,402 | 337,873 | 377,399 |

[r] Revised.
[1] Commodity Exchange Inc. only.
[2] Includes gold in Exchange Stabilization Fund.
[3] Gold held for foreign and international official accounts at New York Federal Reserve Bank.

## PRICES

The Engelhard Industries-London daily final price of refined unfabricated gold began the year at about $306 per troy ounce and remained at about that level for the following 8 weeks. On February 25, the price fell to $284, its lowest point since August 6, 1979. Subsequent domestic and international economic and political developments combined to drive the price to the year's high of $341 in August and to sustain it through yearend at around $320. The Engelhard Industries average for the year was $317.66 per troy ounce, compared with $360.66 per troy ounce in 1984.

**Table 13.—U.S. gold prices[1]**

(Dollars per troy ounce)

| Period | Low (date) | | High (date) | | Average |
|---|---|---|---|---|---|
| 1981 | 391.25 | (Aug. 4) | 599.25 | (Jan. 6) | 459.64 |
| 1982 | 276.75 | (June 21) | 481.00 | (Sept. 7) | 375.91 |
| 1983 | 374.65 | (Nov. 21) | 509.25 | (Feb. 15) | 424.00 |
| 1984 | 307.90 | (Dec. 20) | 405.85 | (Mar. 5) | 360.66 |
| 1985: | | | | | |
| January | 298.15 | (Jan. 28) | 308.40 | (Jan. 18) | 303.19 |
| February | 284.65 | (Feb. 25) | 304.55 | (Feb. 14) | 299.22 |
| March | 287.65 | (Mar. 1) | 330.80 | (Mar. 27) | 304.34 |
| April | 317.15 | (Apr. 4) | 334.65 | (Apr. 15) | 325.31 |
| May | 310.00 | (May 6) | 326.90 | (May 14) | 316.46 |
| June | 312.40 | (June 10) | 325.80 | (June 19) | 316.89 |
| July | 308.65 | (July 2) | 327.90 | (July 31) | 318.20 |
| August | 320.20 | (Aug. 6) | 341.30 | (Aug. 19 and 28) | 330.46 |
| September | 316.65 | (Sept. 18) | 329.65 | (Sept. 26) | 323.18 |
| October | 322.65 | (Oct. 1) | 328.15 | (Oct. 22) | 326.24 |
| November | 322.35 | (Nov. 8) | 331.50 | (Nov. 26) | 325.64 |
| December | 315.90 | (Dec. 11) | 330.00 | (Dec. 31) | 322.76 |
| Average | XX | | XX | | 317.66 |

XX Not applicable.

[1] Engelhard Industries daily quotation.

## FOREIGN TRADE

Net imports of gold continued to increase during most of 1985, probably in response to favorable currency exchange rates. With the exception of gold contained in waste and scrap products, imports of gold-bearing materials again exceeded exports, with total net imports for the year increasing 48% above the 1984 level. Net imports of refined bullion registered substantial gains over net imports of the previous 2 years; in terms of net value, however, the increase was marginal in comparison with that of 1984. Imports of gold-bearing ore and concentrates declined substantially from imports received during 1984, reflecting the precipitous decline during 1984 in imports of gold-bearing copper ore and concentrates. The rate of growth in net exports of waste and scrap slowed considerably from the rate in 1984.

Gold imported in bullion coins declined 26% to about 2.06 million ounces. Imports of South African Krugerrands declined 73% owing to a combination of factors, such as the Presidential banning order of October, the availability of domestic gold investment items, and a shift toward other forms of investment.

## Table 14.—U.S. exports of gold, by country

| Year and country | Ore and concentrates |  | Waste and scrap |  | Doré and precipitates |  | Refined bullion |  | Total[1] |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Quantity (troy ounces) | Value (thousands) | Quantity (troy ounces) | Value (thousands) | Quantity (troy ounces) | Value (thousands) | Quantity (troy ounces) | Value (thousands) | Quantity (troy ounces) | Value (thousands) |
| 1981 | 3,827 | $1,779 | 1,009,101 | $485,794 | 186,493 | $82,976 | 5,237,585 | $2,501,337 | 6,437,006 | $3,071,886 |
| 1982 | 3,092 | 1,028 | 1,149,821 | 427,846 | 180,297 | 69,264 | 1,637,184 | 590,947 | 2,970,394 | 1,089,086 |
| 1983 | 12,757 | 5,190 | 1,175,830 | 469,789 | 69,213 | 26,037 | 1,881,233 | 825,418 | 3,139,033 | 1,326,434 |
| 1984 | 3,298 | 545 | 1,422,849 | 503,237 | 72,470 | 24,502 | 3,482,473 | 1,284,718 | 4,981,090 | 1,813,002 |
| 1985: |  |  |  |  |  |  |  |  |  |  |
| Belgium-Luxembourg | -- | -- | 90,691 | 28,878 | 208 | 74 | -- | -- | 90,899 | 28,952 |
| Canada | 991 | 328 | 516,241 | 157,394 | 73,702 | 23,245 | 2,193,117 | 702,264 | 2,784,051 | 883,230 |
| Colombia | -- | -- | 710 | 220 | -- | -- | 15,042 | 4,563 | 15,752 | 4,783 |
| Dominican Republic | -- | -- | -- | -- | -- | -- | 2,124 | 703 | 2,124 | 703 |
| France | 241 | 40 | 170,538 | 54,399 | -- | -- | 462 | 106 | 171,241 | 54,545 |
| Germany, Federal Republic of | -- | -- | 25,533 | 7,869 | 6,499 | 2,079 | 3,932 | 1,198 | 35,964 | 11,146 |
| Haiti | -- | -- | -- | -- | -- | -- | 2,235 | 515 | 2,235 | 515 |
| Hong Kong | -- | -- | 19,300 | 5,790 | 28 | 17 | 66,468 | 20,344 | 85,796 | 26,151 |
| Italy | 10 | 3 | 2,675 | 847 | 141 | 35 | 1,930 | 603 | 4,756 | 1,488 |
| Japan | -- | -- | 38,959 | 11,278 | 6,267 | 1,611 | 35,742 | 11,498 | 80,968 | 24,386 |
| Mexico | 1,053 | 335 | 27 | 9 | -- | -- | 9,515 | 3,236 | 10,595 | 3,579 |
| Panama | -- | -- | 1,456 | 477 | -- | -- | 18,664 | 5,979 | 20,120 | 6,456 |
| Spain | -- | -- | 3,526 | 1,156 | -- | -- | 1,600 | 534 | 5,126 | 1,690 |
| Sweden | -- | -- | 25,700 | 8,181 | 2,522 | 833 | -- | -- | 28,222 | 9,014 |
| Switzerland | 110 | 55 | 430 | 112 | 3,537 | 1,026 | 338,406 | 110,293 | 342,483 | 111,486 |
| United Kingdom | 10 | 1 | 83,429 | 26,443 | 1,802 | 802 | 191,337 | 55,164 | 276,578 | 82,410 |
| Uruguay | -- | -- | -- | -- | -- | -- | 2,987 | 900 | 2,987 | 900 |
| Other | 33 | 10 | 932 | 359 | 1,068 | 427 | 4,748 | 1,534 | 6,781 | 2,332 |
| Total[1] | 2,448 | 771 | 980,147 | 303,413 | 95,774 | 30,147 | 2,888,309 | 919,433 | 3,966,678 | 1,253,764 |

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

### Table 15.—U.S. imports for consumption of gold, by country

| Year and country | Ore and concentrates | | Waste and scrap | | Doré and precipitates | | Refined bullion | | Total[1] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity (troy ounces) | Value (thousands) | Quantity (troy ounces) | Value (thousands) | Quantity (troy ounces) | Value (thousands) | Quantity (troy ounces) | Value (thousands) | Quantity (troy ounces) | Value (thousands) |
| 1981 | 102,746 | $43,690 | 130,949 | $56,153 | 253,980 | $115,084 | 4,164,476 | $1,942,560 | 4,652,151 | $2,157,487 |
| 1982 | 202,410 | 69,528 | 85,584 | 27,786 | 394,667 | 145,571 | 4,237,669 | 1,650,719 | 4,920,330 | 1,893,604 |
| 1983 | 239,146 | 94,919 | 146,164 | 51,516 | 608,458 | 255,113 | 3,599,188 | 1,575,570 | 4,592,956 | 1,977,118 |
| 1984 | 202,787 | 69,061 | 357,119 | 122,483 | 1,277,146 | 461,763 | 6,031,550 | 2,293,606 | 7,868,602 | 2,946,914 |
| 1985: | | | | | | | | | | |
| Argentina | -- | -- | -- | -- | 230 | 83 | 28,583 | 9,343 | 28,813 | 9,425 |
| Belgium-Luxembourg | 1,408 | 1,066 | -- | -- | 37,019 | 10,441 | 145,401 | 46,372 | 183,828 | 57,880 |
| Bolivia | -- | -- | 106,732 | 35,725 | 23,050 | 7,263 | 26,445 | 8,167 | 156,227 | 51,155 |
| Brazil | -- | -- | 2,448 | 737 | 92 | 23 | 132,844 | 43,548 | 135,384 | 44,309 |
| Canada | 4,894 | 1,557 | 43,357 | 10,161 | 896,715 | 290,957 | 3,889,881 | 1,251,966 | 4,834,847 | 1,554,641 |
| Chile | 1,820 | 264 | 9,646 | 3,041 | 15,181 | 4,939 | 212,327 | 68,995 | 238,974 | 77,239 |
| Dominican Republic | -- | -- | 11,222 | 4,027 | 317,157 | 100,383 | 27,566 | 9,080 | 355,945 | 113,490 |
| Germany, Federal Republic of | 408 | 137 | 253 | 70 | 13,873 | 4,433 | 18,025 | 5,808 | 32,559 | 10,448 |
| Mexico | 6,600 | 2,152 | 13,310 | 4,539 | 5,386 | 1,730 | 7,248 | 2,343 | 32,544 | 10,765 |
| Peru | -- | -- | 834 | 255 | 16,663 | 5,410 | 33,155 | 10,726 | 50,652 | 16,391 |
| Spain | 3,255 | 948 | -- | -- | -- | -- | 25,250 | 7,910 | 28,505 | 8,858 |
| Switzerland | 11 | 4 | -- | -- | 46,558 | 14,806 | 301,645 | 97,689 | 348,214 | 112,498 |
| United Kingdom | -- | -- | 34,816 | 10,494 | 52,712 | 16,707 | 324,538 | 104,412 | 412,066 | 131,613 |
| Uruguay | -- | -- | -- | -- | 623 | 155 | 1,079,137 | 407,453 | 1,079,760 | 407,608 |
| Venezuela | 90 | 20 | 76,455 | 19,842 | 13,622 | 4,161 | 18,803 | 5,998 | 108,970 | 30,021 |
| Yugoslavia | -- | -- | 4,532 | 652 | 1,611 | 523 | 22,779 | 7,336 | 28,922 | 8,511 |
| Other | 18,581 | 5,478 | 63,282 | 17,605 | 20,576 | 6,215 | 67,350 | 22,330 | 169,789 | 51,628 |
| Total[1] | 37,067 | 11,628 | 366,887 | 107,147 | 1,461,068 | 468,227 | 6,360,977 | 2,109,475 | 8,225,999 | 2,696,478 |

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

Continuing a trend that began in 1980, world gold mine production increased again during 1985. About 45% of the world mine output came from the Republic of South Africa, with the remainder, in descending order of magnitude, from the U.S.S.R., Canada, the United States, Brazil, China, Australia, and 56 other countries. Gold is also produced in small quantities in a dozen or so other countries for which production data are not available.

Consolidated Gold Fields, in its annual summary of world gold supply and demand, reported that the supply of gold available to commercial purchasers in the market economy countries in 1985 was about 41.4 million ounces or nearly 5 million ounces less than that of 1984. Following 2 years during which central banks and government-controlled investment institutions, which together make up the official sector, were net sellers of gold to the market, the official sector in 1985 made net purchases amounting to over 4.3 million ounces.

Gold Fields estimated that consumption of gold in the commercial sectors of the market economy countries was about 39.6 million ounces, or essentially the same as that of 1984. Gold consumed in 1985 in the market economy countries was divided, in millions of troy ounces, with 1984 consumption in parentheses, between the following end-use categories: jewelry, 28.9 (26.6); electronics, 3.6 (4.0); dental, 1.7 (1.6); other industrial and decorative uses, 1.6 (1.8); medallions and unofficial coins, 0.4 (1.4); and official coins, 3.4 (4.2).[12]

A brief description and analysis of the salient features of the mineral industries, including gold, of Australia, Canada, and Oceania was published by the Bureau of Mines in 1985.[13]

**Australia.**—The resurgence in Australian gold production, which began in 1981, continued in 1985 with production exceeding 1.8 million ounces, up 46% over that of 1984 and greater than in any year since 1915. The year's comparatively high gold prices in terms of Australian dollars, and the income tax-free status of gold mining combined to further stimulate industry's interest and action. Again, as in recent years, Western Australia was the principal producing State and experienced the greatest gold exploration and mining activity.

Substantial depreciation of the Australian dollar in March and again in November 1985 served to increase the gap between U.S.-dollar-denominated gold prices and prices denominated in Australian dollars (A$). The price began the year at nearly A$370, compared with a London price of about US$308, peaked at A$510 in April then ranged from A$450 to A$500 for the rest of the year.

Highlights of Australian gold developments in 1985 were summarized by the Australian Bureau of Mineral Resources (BMR).[14] In addition to addressing developments at Australia's gold mines, the BMR noted that retreatment of old dumps for gold left by previous treatment was increasing; at least 53 dumps were being retreated, with the scale of the operations ranging from the Mount Morgan Ltd. and Anglo American Gold Pty. Ltd. 38,600-ounce-per-year venture in Queensland to smaller operations with individual annual capacities of 3,000 ounces or less. Throughout the country, at least 26 placer mines operated, most of them small; the total does not include many small 1- to 2-person operations. According to the BMR, out of the total funds directed toward mineral exploration in Australia exclusive of petroleum, about 40% was allocated to the search for gold.

April 4 marked the official opening of the new Kidston Mine, Australia's largest gold mine. The new mine is in the historic Oaks Goldfield approximately 180 miles northwest of Townsville in the State of Queensland. Ore production at the new open pit started in January, and the first gold was poured in February. The new mine, 70% owned by Placer Development Ltd. and 30% owned by various domestic interests, produced more than 206,000 ounces of gold during its first year of operation. At full production, Kidston was expected to yield 281,000 ounces of gold and 164,000 ounces of silver per year.

A significant gold discovery was made in early 1985 in Queensland's Drummond Basin about 35 miles south of Charters Towers and 90 miles southwest of Townsville, by Pajingo Gold Mines Pty. Ltd., a subsidiary of Battle Mountain Gold of Houston, TX. Initial drilling on the Pajingo Prospect reportedly produced several extremely high-grade intersections; one, for example, reportedly included 6.6 feet of core assaying 45.57 ounces of gold per ton. Subsequent drilling and examination of the ore body, designated as the "Janet A. Lode Zone," resulted in the identification of reserves bearing an estimated 500,000 ounces of gold and more than 1.8 million ounces of silver that should be minable using surface mining techniques. Six other areas, including the Janet B. Zone about 0.5 mile away from the Janet A. Zone, have been scheduled for investigation in the near future. The company has authority to prospect about 2,000 square miles in the Pajingo area. Nearby, another company, North Queensland Resources, reportedly held a small unexplored prospect designated as the "Highway gold prospect." Elsewhere in Queensland, the Mount Leyson gold deposit, a prospect held jointly by Noranda Pacific Ltd. (a joint venture of Noranda Australia, the Broken Hill Pty. Co. Ltd. (BHP), and the Electrolytic Zinc Co. of Australia Ltd.) and Pan Australia Mining Ltd., had reached the feasibility stage and was believed likely to begin production by 1987. Several other gold properties in the State were under investigation, with several targeted for production in the near future.

Western Mining Corp. Holdings Ltd. (WMCH) and its partner BP Australia Ltd. decided to develop the huge Olympic Dam project at Roxby Downs, South Australia. In addition to producing copper and uranium, the mine was expected to produce gold at a rate of about 96,000 ounces per year shortly before or following the mine's scheduled opening as a base metal producer in 1988.

In the Northern Territory, the Pine Creek gold mine of Renison Goldfields Consolidated Ltd. (RGC) and Enterprise Gold Mines NL began production in late October. The new mine at Pine Creek was to be operated by the partners' company, Pine Creek Consolidated Ltd., and was expected to produce 53,000 ounces of gold and 20,000 ounces of silver annually. In the Tanami area of the Northern Territory, North Flinders Mines Ltd. continued exploration and planning at its Granites project. The company planned to bring the new mine into production by July 1986 at an annual rate of about 65,000 ounces per year. Exploration reportedly identified five additional deposits that could add substantially to the project's established ore reserves. In other developments, Noranda Pacific continued exploration of a significant gold discovery made in 1984 at Coronation Hill. Drilling at the project in 1985 indicated a large reserve of ore minable by surface methods, while geological studies suggested that a much larger potential may exist. Platinum and palladium of unspecified quantity were reportedly associated with the discovery. Near yearend, Peko Mines, part of Peko-Wallsend Group Ltd., completed construction of surface and shaft-hoisting facilities at its Argo Mine (formerly Explorer 46) under development near Tennant Creek. Also near Tennant Creek, Nobles Nob gold mine ceased operation on January 14, after 37 years. Milling of stockpiled ore was expected to continue at least through midyear. Depletion of economic reserves was cited as a reason for the closure.

Developments in the State of Western Australia, which accounted for about 70% of Australia's production in 1985, continued to dominate the country's gold mining scene. At least six new mines began production during the year, and improvements were completed at numerous others; exploration was very active. WMCH's gold circuit at the Kambalda nickel operation produced 95,523 ounces for the fiscal year ending in September. The company also began heap leaching low-grade ore from the opencut at the Victory Mine. Production from WMCH's other Western Australian gold properties at Kalgoorlie, Lancefield, Mount Magnet, and Norseman, and not including production at affiliated Kalgoorlie Mining Associates (KMA) facilities, amounted to 223,964 ounces for the 12 months ending in September. Gold production by KMA at its Mount Charlotte and Fimiston operations amounted to 234,057 ounces during the fiscal year.

New mines that began operations in Western Australia during the year included the following: Esso Exploration and Production Australia Inc. and its partners dedicated the new 80,000-ounce-per-year Harbour Lights Mine at Leonora in July. AUR NL started treating ore from its Mount Martin and Good Hope Mines between Kalgoorlie and Kambalda. AUR poured its first gold in April; production was expected to be 10,000 to 15,000 ounces per year. Brunswick Oil NL began operations at its new open pit Galtee More Mine 5 miles northwest of Mount Magnet. Production was expected to be 45,000 ounces per year; a new 200,000-ton-per-year mill was scheduled for operation in early 1986. Endeavour Resources Ltd. commissioned its new 40,000-ounce-per-year Bluebird Mine and carbon-in-leach treatment plant near Meekatharra. Near Kalgoorlie, Windsor Resources NL and partners began production near yearend at the Mount Percy open pit. The new $9 million mine was expected to yield 39,000 ounces per year. The Paddington open pit mine of Pancontinental Mining Ltd., at Broad Arrow, 20 miles north of Kalgoorlie, was commissioned in May. The first gold was poured in June; annual production was expected to be 90,000 ounces. Finally, BHP's new Gimlet South, or Ora Banda Mine at Ora Banda, began production at an initial annual rate of 10,000 ounces.

At Western Australia's largest gold mine, the Telfer Mine, east of Nullagine, Newmont Holding Pty. Ltd. and BHP announced plans to increase the mine's production capacity from 140,000 to 190,000 ounces per year. The expansion program was scheduled for completion by September 1986.

Australia Mining NL announced in early 1985 that because of depletion of economic ore reserves the Mount Henry Mine at Norseman was placed in care-and-maintenance status pending the discovery of new reserves and/or an increase in the price of gold.

In August, the Government of Australia approved plans by the Western Australian government's Perth Mint to produce gold coins to compete in the international market with gold coins offered by other nations. The plans reportedly called for the minting of 200,000 to 500,000 coins of 99.99% purity ranging in weight from 0.10 to 1 troy ounce, to be marketed during the first half of 1986.

**Brazil.**—The gold rush under way in Brazil over the past several years continued to moderate, and development became more organized. At Serra Pelada, in the State of Pará, production dropped from a 1983 peak of about 400,000 ounces to an estimated 70,000 ounces in 1985; most of the estimated 30,000 to 40,000 independent miners, or "garimpeiros," who were working in the mine's enormous hand-dug pit during the peak years have since been drawn to the many other isolated gold rush camps scattered throughout the northern part of the country. Gold-bearing rivers such as the Tapajós and others flowing out of the Andes Mountains and along the frontier between Brazil and Bolivia continued to be the largest centers of garimpeiro activity.

Efforts were continued by the Government to develop a more accurate accounting of the country's gold production, especially that produced by garimpeiros who, attracted by premium gold prices offered outside of the country, reportedly sold their unreported production to smugglers, or simply used it as a medium of exchange in the frontier areas. Calls for official guidelines and policy directives aimed at achieving greater control over gold smuggling and objectionable garimpeiro mining practices were made on several occasions during the year by gold mining industry and Government representatives.

In the State of Minas Gerais, the Mining Div. of General Mining Union Corp. Ltd. (Gencor), of the Republic of South Africa, continued to develop its underground São Bento gold mine. The mine's new gold recovery plant was to incorporate a pressurized leaching system designed to maximize gold recovery from the highly refractory ore. Commissioning of the new mine was scheduled for the end of 1986. Production was expected to be about 60,000 ounces per year. At Paracatu, between Brazilia and Belo Horizonte, a large placer deposit reportedly containing 3 million ounces of gold, 1.4 million ounces of silver, and nearly 0.5 million ounces of platinum was discovered by RTZ Mineração Ltd., the Brazilian subsidiary of The Rio Tinto Zinc Corp. PLC, of the United Kingdom. The deposit, known as the Morro do Ouro, was the result of more than 4 years of exploration by RTZ. Reportedly at yearend, RTZ had formed a joint venture with Autram Mineração e Participações S.A. to proceed with development of the property. Production was scheduled to begin in 1987 at a rate of about 100,000 ounces of gold per year. Concurrently, Autram was reportedly involved with a Canadian partner, Treasure Valley Explorations, of Toronto, in developing a large placer deposit along the Teles Pires River in the State of Mato Grosso.

At Nova Lima, Mineração Morro Velho S.A. (MMV), an indirect subsidiary of the Anglo American Corp. of South Africa Ltd. (AAC), and its partner, the Bozzano Simonsen Group, moved closer to a targeted 1987 completion of an expansion program at its Raposos-Cuiaba project. The $160 million program was expected to increase the company's production capacity in the State by about 160,000 ounces, to 300,000 ounces per year. MMV also operates the old Morro Velho Mine near Nova Lima, where stratabound, sulfide-hosted gold has been mined since 1835, and the Jacobina Mine in the State of Bahia.

At the end of January, Cia. Vale do Rio Doce (CVRD), the Brazilian state mining company, produced the first gold from its new Araci Mine, also known as the Fazenda Brasileiro. Construction of the open pit mine, near Serrinha in the State of Bahia, was completed between January and September 1984 and is Brazil's first heap-leaching operation. About 16,000 ounces was expected to be produced annually. CVRD's plans to take over development of the Serra Pelada Mine in the State of Pará were reportedly postponed for several years to allow garimpeiros there to continue.

An investigation of the genesis and formation of gold deposits in the Precambrian shield of Brazil concluded that the best potential for future discoveries of lode gold deposits should be in greenstones and younger Precambrian conglomerates.[15] A genetic model was proposed that indicated repeated recycling of gold through geological time.

**Canada.**—Canadian gold production increased for the fifth consecutive year, reflecting the continuing momentum of both Canadian gold exploration and mine development.

Gold production in Ontario increased 13% during the year, and developments in that Province were highlighted by the opening of three large underground mines at Hemlo. Just 3 years from discovery and 2 years since construction began, the Golden Giant Mine at Hemlo poured its first 1,000-ounce bar of production gold. The Golden Giant Mine is owned by Noranda Mines Ltd. and its partners Golden Sceptre Resources Ltd. and Goliath Gold Mines Ltd. Production at the Golden Giant was expected to reach 330,000 ounces per year by 1988. At the end of May, Teck Corp. and its partner International Corona Resources Ltd. poured their first gold at the Teck-Corona Mine. Annual production at the new Hemlo facility was expected to be about 250,000 ounces by 1987. Nearby, Lac Minerals Ltd., of Toronto, brought its Page-Williams Mine on-stream in December. Production from this mine was to reach 200,000 ounces in 1986 and reportedly could rise to 400,000 ounces per year by 1989. Believed to be the most significant discovery in over 50 years in Canada, the Hemlo deposit may eventually increase Canadian production from its present 2.7 million ounces per year to nearly 3.5 million ounces.

At the Detour Lake Mine, 120 miles northeast of Timmins, Ontario, operations at the open pit were scheduled to end in 1986, and at about the same time, a 17-month shutdown was reportedly planned to accommodate changes in the mine's development plan. In midyear, Kidd Creek Mines Ltd., Toronto, announced a decision to expand crushing capacity and build a new gold recovery plant at its Kidd Creek copper-zinc-silver-gold mine at Timmins. The expansion was to accommodate production from the company's new Hoyle Pond and Owl Creek Mines. The Hoyle Pond Mine, near Timmins, was scheduled to begin production in early 1986 and was expected to produce about 45,000 ounces of gold per year. The Owl Creek open pit mine, which began production in 1982, is just west of Hoyle Pond and produces about 25,000 ounces of gold per year.

Other Canadian gold mines moving toward production in the near future include Sherritt Gordon Mines Ltd.'s new 70,000-ounce-per-year MacLellan Mine near Lynn Lake, Manitoba; Mascot Gold Mines Ltd.'s open pit project at Hedley, British Columbia; and Total Erickson Resources Ltd.'s Mount Skukum project, about 40 miles south of Whitehorse in the Yukon Territory. Corona's Cullaton Lake property in the Northwest Territories was closed, as was Teck's Lamaque Mine at Val d'Or, Quebec.

Although gold exploration activity was high throughout the gold-producing areas of Canada, it was especially high in the Maritime Provinces and in the Province of Quebec. Stimulated by the discovery near yearend by Teck Explorations Ltd. and its partners Golden Hope Resources Inc. and Golden Group Explorations Inc. of a small, high-grade gold, silver, copper, and zinc deposit near Casa Berardi, in Estrades Township, northwestern Quebec, numerous companies accelerated a rush to secure land positions in the area. Inco, one of the original companies that had been exploring in the area since 1981, touched off the rush when significant gold values were intersected during a drilling program along an extension of the main ore zone of its Golden Pond deposit, where Inco, with its partner Golden Knight Resources Ltd., had earlier begun an underground exploration program. At yearend, several dozen companies had secured land positions in the Casa Berardi area, and a few new gold strikes had reportedly been made. Investor interest, based largely on the results of preliminary drilling in the area, was reflected in a large early December increase in speculative trading activity on the Vancouver, British Columbia, stock exchange.

On the southwest coast of the island of Newfoundland, BP Resources Canada Ltd. continued to evaluate its Chetwynd gold deposit. By yearend, the company had completed 58 drill holes indicating preliminary reserves of about 1.6 million ounces of gold. A 9,500-ton heap-leach recovery test showing a 61% recovery rate was also conducted. Development of the property was expected to begin in 1986. Gold discoveries near the island's south coast, at White Bay on the north coast, and to the north in Labrador, also stimulated major claim staking and land acquisition in the Province of Newfoundland. The number of new claims staked reportedly exceeded 13,000, and more than 27,000 were reportedly in good standing at yearend. About 30 companies were involved in the new claim activity. Gold exploration activity was also reviving in the Provinces of New Brunswick and Nova Scotia, where new discoveries in recent years were prompting a reexamination of old goldfields and grassroots efforts in unexplored areas.

As a result of restrictions near yearend on the importation of South African Krugerrands by a number of countries, the Canadian Maple Leaf bullion coin market benefited significantly, and sales reached an all-time high, rising from 1 million ounces in 1984 to nearly 1.9 million ounces in 1985.

**China.**—The Government of China continued to formulate economic policies and provide incentives aimed at rapidly increasing the country's production of gold, which, as an export commodity, may be quickly liquidated to earn much-needed foreign exchange credits. At a gold mining conference in October, China's New Minister of Geology and Mineral Resources indicated that the Government planned to double the country's present annual output by 1990. To encourage greater production and discourage gold smuggling and hoarding, the Government began to maintain the price at levels in line with the world market price. A crackdown on gold smuggling was intensified during the year, and nearly 1,000 persons were reportedly fined or imprisoned. Gold was reportedly used as a medium of exchange for the purchase of luxury and restricted goods, such as television sets and drugs from outside the country.

The Government continued to step up its efforts to sell its gold production as fabricated products on both domestic and international markets. The popularity of Gold Panda coins minted in Shanghai by the China Mint Co., an affiliate of China's Central Bank, continued to grow, and the Government was reportedly continuing to encourage domestic fabrication of jewelry products in response to increasing demand by the Chinese people.

Reports of Chinese gold discoveries and new mine developments continue to increase every year. Gold was reportedly being mined in 400 Chinese counties. China's largest deposit, the Jiaojiashi gold mine in northern Shandong Province, was reportedly estimated to contain about one-third of the country's verified primary gold reserves. Information released on the discovery suggested that the deposit may be a large low-grade disseminated-type deposit.

**Colombia.**—Apparently stimulated by a 1984 Government decision to pay a 30% premium over world gold prices, gold production in Colombia registered a nearly 44% increase over that of 1984. Foreign and domestic participation in gold ventures throughout Colombia remained at a high level throughout the year. The Instituto Nacional de Investigaciónes Geológico-Mineras, an autonomous Government agency responsible for mineral exploration and preliminary mining studies, issued a report summarizing the most promising areas to prospect for new lode and placer deposits of gold and silver in Colombia. The area with the best potential for vein-type lode gold was reported to be the Cordillera Central because of extensive fracturing and fault structures; the volcanics on the western edge of the Cordillera were reported to be the most promising formations for discoveries of disseminated-type deposits. The promising placer zones detailed in the report offer the best prospect for discovery and increased gold output in the near term, with the Guaninía Zone near Brazil ranked as having the best potential for placer gold discoveries. The report included maps and a selected bibliography.[16]

**Japan.**—Interest in gold as an investment vehicle, as well as gold use in fabricated products, especially jewelry, continued to expand in 1985, and as a consequence, Japan moved closer to being one of the world's leading gold markets. Japanese interest and activity directed toward gold exploration and mine development also continued at a high level.

In July, Sumitomo Metal Mining Co. Ltd. began production at its rich Hishikari gold mine in Kagoshima Prefecture on Japan's southern island of Kyushu. The deposit, a classic epithermal (low-temperature) deposit characteristic of the Island Arc volcanic setting, was reportedly discovered in 1978 by an airborne electromagnetic survey conducted in an area previously thought not to host precious metals deposits. The grade of the ore under development was reportedly about 2.3 ounces per ton; 3.9 million ounces of reserves had been delineated by the time production began. Production costs for the planned 174,000-ounce-per-year operation were expected to be among the lowest in the world. Exploration in the Hishikari area by Japan's Metal Mining Agency reportedly led to the discovery of a gold prospect between Sumitomo's new mine and the Kushikiso gold mine of Mitsui Mining & Smelting Co. Ltd.

Initial assays of material returned from drilling a new well at a hot spring at Mount Aso, near the existing Hita gold mine in Kyushu's Oita Prefecture, reportedly showed about 0.6 ounce of gold per ton, plus silver and copper values.

Yatani Mining Co. Ltd., a subsidiary of Mitsubishi Metal Corp., reportedly discovered a high-grade gold occurrence in its Yatani lead and zinc mine, in the Yamagata Prefecture of northern Honshu.

**Oceania.**—This area has in recent decades yielded significant precious and base metals deposits, such as those developed in Papua New Guinea at Ok Tedi, on the mainland, and at Panguna, on Bougainville Island. Exploration over the past several years has resulted in the discovery of additional deposits, and discoveries announced during 1985 suggest that the rate of success is accelerating.

Interest was generated in 1985 by the release of a report detailing the discovery of anomalous gold values on the Island of Palau, along the Pacific Rim in the Caroline Islands north of New Guinea. According to the report, a brief reconnaissance of the island by the U.S. Geological Survey had resulted in the discovery of a large, as yet unassessed, epithermal gold system.[17]

In Papua New Guinea in the Enga Province of the Western Highlands, between Mount Hagen and Ok Tedi, exploration continued at the Porgera joint venture by Placer (P.N.G.) Pty. Ltd. and its partners Mount Isa Mines Ltd. and RGC. The partners had outlined a large reserve of gold- and silver-bearing ore, much of which is not recoverable by simple cyanide leaching. Metallurgical tests, however, demonstrated that a flotation and pressure oxidation process would be technically feasible. The partners planned to drive an exploration adit in 1986 to more fully evaluate the high-grade portion of the ore body. Placer also continued exploration at its gold and silver property on Misima Island, to the east of the mainland coast.

A partnership of Nord Resources Corp., Kennecott Explorations (Australia) Ltd., and Niugini Mining Ltd., exploring in the Tabar Islands group of Papua New Guinea, encountered encouraging results at three gold prospects on Tatau Island and at four prospects on Simberi Island, 5 miles to the north. To the southeast, in the Linetz-Lamond area of Lihir Island, the partners continued to evaluate a gold discovery announced in 1984. Preliminary diamond drilling results released at yearend 1985 reportedly indicate that a potential gold reserve of nearly 12 million ounces may exist. The partners were also exploring on the island of New Hanover, Woodlark Island, and in the Ramu River area of mainland Papua New Guinea. Also in Papua New Guinea, Esso PNG Inc. and City and Suburban Properties Ltd., of Sydney, Australia, were reported to be prospecting in the D'Entrecasteaux Island group of Milne Bay, in the Feni Islands, and on the island of New Britain, while Newmont Mining was reportedly prospecting in the Tanga Islands.

Activity increased in the Solomon Islands, with interest centering around the old gold deposits on Guadalcanal Island; Cyprus Minerals Co. was reportedly prospecting in the Gold Ridge area, while an Australian company, Zanex Ltd., was reportedly preparing to start mining a placer deposit on the Matepono River with its partner, a local company, Mavu Gold Development Ltd.

In 1985, 95% of the gold produced in Oceania came from two large mines in Papua New Guinea, the Panguna and Ok Tedi operations. At Panguna, on the Island of Bougainville, Bougainville Copper Ltd. produced more than 462,000 ounces of gold as a byproduct of its copper mining operations in 1985. The decline in gold production from the 1984 level of about 504,000 ounces reflected a continuing decline in the gold content of the ore mined; production of mined ore and concentrate had increased 7% over that of 1984.

On the mainland of Papua New Guinea, the new Ok Tedi gold and copper mine, which began production in 1984, produced an estimated 546,000 ounces of gold despite a 5-week hiatus beginning in February. The break in production stemmed from a disagreement between the Government of Papua New Guinea and the mine's owners concerning the time at which the second, or copper, development phase would begin, relative to the completion of the first mining phase—the extraction of the mine's gold-rich cap. An agreement was reached in March whereby the operators would accelerate preparations for the development of the copper production phase. The new mine is one of the largest gold mines in the world outside of the Republic of South Africa and the U.S.S.R. Situated at Mount Fulbian in the rugged Star Mountains near the border between Papua New Guinea and Indonesia, the mine was developed by two U.S. companies, plus a West German consortium and, later, included the Government of Papua New Guinea; the associates together make up Ok Tedi Mining Ltd. The location is perhaps one of the most inhospitable in the world today, with normal mean rainfall of 312 inches distributed over a rainy season lasting for 339 days per year.

Near the north mainland coast, New Guinea Goldfields Ltd. (NGG), controlled by RGC and Consolidated Gold Fields, produced about 11,000 ounces of gold and 7,800 ounces of silver from lode and placer mine operations at Wau. The company began construction of a new 440,000-ton-per-year mill and carbon-in-pulp plant that was scheduled for completion in early 1986.

Other gold-producing countries around the southern Pacific Rim include Indonesia, Fiji, and New Zealand. They registered production increases during the year of 7%, 24%, and 108%, respectively. Each also registered a substantial increase in gold exploration activity as well as development at new or existing operations.

**Peru.**—In May, the Government of Peru, responding to a need to attract investors to the country's gold mining industry by providing more flexibility in its gold mining laws, modified a number of regulations pertaining to gold mine investment and/or reinvestment programs. Reinvestment regulations were simplified and some burdensome aspects were removed altogether. Direct investment programs, where previously only reinvestment was permitted, were added and both kinds of programs together were structured to clarify investment incentives in the areas of minerals rights, exploration, equipment purchases, construction of infrastructure and access facilities, and installation of advanced recovery processes.

**Philippines.**—Gold production in the Philippines increased slightly in 1985. Despite gold rushes reportedly under way in several Provinces, some marginal gold and copper operations were forced to suspend work because of rising mining costs and low world metals prices.

The Benguet Corp., the country's largest gold producer, reported a drop in gold output from its five underground gold mines near Baguio City in Benguet Province and its open pit Dizon copper-gold mine in Zimbales Province. Production from the Baguio City mines amounted to 112,000 ounces compared with 114,000 ounces in 1984. During the year, the company began open pit mining at two mineralized areas associated with the deposit cut by the five underground operations. The company also acquired a controlling interest in the Ltogon Mine adjacent to its Acupan Mine. At the Dizon Mine and concentrator in San Marcelino, production of byproduct gold from the copper mining operations was 129,000 ounces, compared with 144,000 in 1984. In 1985, nearly 16 million tons of copper-gold ore plus waste rock were moved. The decline in gold production was a direct result of a 12% reduction in the gold content of the ore mined during the year plus a slight drop in gold recovered by the mill. Benguet also conducted extensive exploration and development work at its Paracale Gold project in Camarines Norte Province, and exploration for gold, copper, and other metals in various Philippine Provinces until financial limitations forced many projects to be suspended toward yearend.

Atlas Consolidated Mining and Development Corp. reported that 160,002 ounces of gold was produced at its operations on Cebu and Masbate Islands, compared with nearly 190,000 ounces in 1984. The heap-leaching plant at the Masbate Gold Operation (MGO), which began production in late 1984, produced 6,301 ounces of gold during its first full year of operation. Gold produced at MGO's open pit operation amounted to nearly 79,000 ounces, or slightly less than in 1984. Exploration by Atlas was held in abeyance during the year pending improvement in the outlook for its products.

Exploration for gold was conducted by a number of other companies operating in the islands. RGC continued drilling at its Tirad project, and prospecting on Bohol Island by Colfax Energy Ltd. and its partner Black Gold Oil & Gas Ltd. reportedly detected promising gold values.

Gold rushes were reported on the islands of Mindanao and Negros, where controls were imposed on the various operations following problems associated with unsafe working conditions and gold smuggling.

**South Africa, Republic of.**—Effective April 1, the mining tax surcharge paid by all domestic gold and diamond mines was increased by 5%, to 25%. A 34% decline in the value of the rand against the U.S. dollar, plus relatively stable dollar-denominated gold prices, combined to produce increased revenue for the country's gold mines.

From September 1983 through the end of 1984, the South African Reserve Bank had been paying for domestic gold mine production with dollars. Beginning in January 1985, this payment to the mines in dollars was reduced by one-half with the remaining one-half paid in rands, and by December, the bank reverted to paying for production exclusively in rands.

Superimposed on these and other internal developments, especially during the second half of the year, were actions taken by several foreign governments to ban the importation of Krugerrands and to impose restrictions on business-related activities with the Republic of South Africa.

In the meantime, labor strife continued to mount and manifest itself at some of the country's gold, coal, and platinum mines. On April 26, about 15,000 gold miners were fired following their participation in a reportedly illegal 24-hour strike for higher wages. The majority of the dismissed miners were employed at the Vaal Reefs Mine of AAC; concurrently, Anglovaal Ltd. fired a number of strikers at its Hartebeestfontein Mine. A strike by the National Union of Mineworkers (NUM) against selected South African gold and coal producers began on September 3, but was called off the following day when only a small percentage of NUM's estimated 150,000 members participated.

Of the nearly 21.6 million ounces of gold produced in the Republic of South Africa during the year, 20.5 million ounces was produced by the 33 mines that together represent the membership of the Chamber of Mines of South Africa. The remainder was recovered by small independent gold producers or as a byproduct of other mining sectors. The total ore milled by Chamber members, including ore milled by producers of byproduct and coproduct uranium, amounted to 115.3 million tons, averaging 0.18 ounce of gold per ton; in 1984, 111.5 million tons, averaging 0.19 ounce per ton, was milled. Working costs for South African gold mines in 1985 averaged[18] $155.27 per ounce and ranged from $87.69 per ounce at the Kloof Mine to $320.88 per ounce at East Rand Proprietary. Production by the six major mining groups was as follows, in million ounces: AAC, 7.7; Gold Fields of South Africa Ltd., 4.1; Gencor, 3.7; Rand Mines Ltd., 2.1; Johannesburg Consolidated Investment Co. Ltd. (JCI), 1.6; and Anglovaal, 1.2.

In terms of individual mine output, the largest South African gold mines, in millions of ounces of production, were Vaal Reefs with 2.6; Driefontein Consolidated with 2.1; Western Holdings, Buffelsfontein, and Western Deep Levels with about 1.2 each; and Harmony with just over 1.0. Estimates of fully developed or blocked-out gold ore reserves reported by the Chamber of Mines at the end of 1985 amounted to nearly 500 million tons, containing, on average, about 0.30 ounce of gold per ton. A comprehensive review of South African gold mining including historical and statistical details on production, labor, and mine financing was published in 1985.[19]

In an attempt to increase production and reduce working costs, AAC continued to seek approval of its previously announced plans to merge four of its gold mining companies in the Orange Free State to form Free State Consolidated Gold Mines Ltd., also known as Freegold. The merger, one that would create the world's largest single gold mine, producing about 3.6 million ounces and employing 105,000 people, had received Government approval by yearend but was yet to be approved by shareholders of the affected companies. Gold Field's Kloof Gold Mining Co. Ltd. announced plans to establish a new division, the Leeudoorn Div., to exploit recently discovered ore reserves near its existing operations in the Transvaal. A new main shaft and ventilation shaft connecting the existing workings with the new reserve area were under construction near yearend. Plans called for a doubling of milling capacity by the end of the century. Gencor announced that its new Beatrix Mine in the Orange Free State, which began production in late 1983, had attained its planned full production rate of more than 2.2 million tons of ore per year.

Exploration continued for new gold ore bodies and extensions to existing deposits in the Republic of South Africa. In the Orange

Free State, JCI and AAC completed their drilling and exploration program in the Theunissen District and reportedly decided to proceed with the sinking of two prospect shafts at the site, known as the Joel Prospect. In the Barberton region of the eastern Transvaal, Southland Energy Corp., a U.S. company, reportedly completed its first-phase exploration program at the old Makonjwaan and Imperial Mines. Favorable preliminary drilling results reportedly led the company to propose a broader program of exploration to several potential partners.

U.S.S.R.—Estimated net exports of gold from the U.S.S.R. and the centrally planned economy countries to the market economy countries were reported to have increased for the second consecutive year, rising from nearly 6.6 million ounces in 1984 to 6.8 million ounces or more in 1985.[20]

### Table 16.—Gold: World mine production, by country[1]

(Troy ounces)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina | 14,757 | 20,319 | 23,374 | 22,120 | 22,500 |
| Australia | 590,737 | 866,815 | 983,522 | 1,257,125 | [3]1,832,590 |
| Bolivia | 66,372 | 40,146 | 49,217 | 40,827 | 30,000 |
| Brazil[e] [4] | 1,200,000 | 1,500,000 | 1,750,000 | 1,750,000 | 2,000,000 |
| Burundi | [e]100 | [e]100 | 272 | 1,115 | 1,100 |
| Cameroon | 316 | 136 | 261 | [e]250 | 250 |
| Canada | 1,672,893 | 2,081,230 | 2,363,411 | [r] [e]2,638,000 | 2,747,000 |
| Central African Republic | 1,386 | 1,000 | 2,492 | 6,953 | 7,000 |
| Chile | 400,479 | 543,569 | 570,971 | 541,051 | [3]554,281 |
| China[e] | 1,700,000 | 1,800,000 | 1,850,000 | 1,900,000 | 1,950,000 |
| Colombia | 529,214 | 472,674 | 438,579 | 799,889 | 1,150,000 |
| Congo | 48 | 83 | 267 | 101 | 150 |
| Costa Rica[e] | 20,000 | 27,000 | 30,000 | 35,000 | 35,000 |
| Dominican Republic | 407,813 | [r]386,309 | 354,023 | 338,272 | [3]337,150 |
| Ecuador | [r]1,286 | 1,601 | 608 | [e]1,000 | 1,000 |
| El Salvador | 3,883 | 3,300 | 650 | 285 | 280 |
| Ethiopia[e] | [3]11,930 | 12,000 | 14,000 | 15,000 | 15,000 |
| Fiji | [r]30,833 | [r]45,750 | 40,124 | 48,515 | [3]59,961 |
| Finland | 31,893 | 36,780 | 25,206 | 28,067 | 28,000 |
| France | 36,362 | 67,967 | 71,659 | 70,279 | 70,000 |
| French Guiana | [e]4,000 | 5,231 | 8,038 | 10,127 | 12,000 |
| Gabon[e] | 550 | 550 | 550 | [r]1,325 | 1,000 |
| Germany, Federal Republic of | 3,051 | 1,813 | [e]1,900 | [e]1,500 | 1,200 |
| Ghana | 341,000 | 331,000 | 276,000 | 287,000 | [3]299,363 |
| Guyana | 19,263 | 7,347 | 4,607 | 11,131 | [3]10,323 |
| Honduras | 1,579 | 1,711 | 2,151 | 2,784 | 2,500 |
| Hungary[e] | 60,000 | 50,000 | 30,000 | 20,000 | 20,000 |
| India[5] | 79,875 | 71,935 | 70,158 | 65,234 | 59,000 |
| Indonesia[6] | [r]54,241 | [r]71,878 | 76,888 | 78,677 | 84,500 |
| Japan | 99,242 | 104,136 | 100,921 | 103,519 | [3]158,567 |
| Kenya | 100 | 21 | 100 | 600 | 600 |
| Korea, North[e] | 160,000 | 160,000 | 160,000 | 160,000 | 160,000 |
| Korea, Republic of[6] | 43,147 | 55,750 | 72,083 | 79,156 | 80,000 |
| Liberia[e] [7] | 16,720 | 12,656 | 15,400 | 10,500 | 12,000 |
| Madagascar[e] | 110 | 110 | 110 | [r]130 | 130 |
| Malaysia: | | | | | |
| Peninsular Malaysia | 5,691 | [r]5,788 | 5,792 | 7,041 | 5,800 |
| Sabah | [r]69,563 | [r]84,614 | 82,662 | 82,012 | 82,000 |
| Sarawak | 67 | [r]23 | 161 | 474 | 4,600 |
| Mali[e] | 16,000 | 13,000 | 13,000 | 16,075 | 16,000 |
| Mexico[8] | 198,594 | 214,349 | 198,177 | 270,998 | 285,000 |
| Namibia | [e]6,000 | 7,395 | 7,459 | 6,302 | [3]6,237 |
| New Zealand | 6,071 | 7,775 | 9,667 | 21,605 | [3]45,011 |
| Nicaragua | 61,913 | 54,384 | 46,428 | [r] [e]35,000 | [3]24,491 |
| Papua New Guinea | 540,325 | [r]589,258 | 579,407 | [e]835,000 | 1,050,000 |
| Peru | 161,590 | 157,667 | 165,576 | 198,691 | [3]223,447 |
| Philippines | [r]758,306 | [r]834,431 | 816,536 | 786,896 | [3]809,735 |
| Portugal | 10,931 | 6,783 | 9,603 | 9,100 | 9,000 |
| Romania[e] | 65,000 | 65,000 | 65,000 | 65,000 | 65,000 |
| Rwanda | 1,204 | 286 | 623 | 240 | 250 |
| Sierra Leone[9] | 3,435 | 8,729 | 12,000 | 18,233 | 18,000 |
| Solomon Islands | 1,050 | 1,318 | [e]1,100 | 2,572 | 3,000 |
| South Africa, Republic of | 21,121,157 | 21,355,111 | 21,847,310 | 21,906,619 | [3]21,566,368 |
| Spain | 98,381 | 109,858 | 162,296 | 123,330 | 125,000 |
| Sudan[e] | 300 | 400 | 500 | 1,500 | 1,500 |

See footnotes at end of table.

Table 16.—Gold: World mine production, by country[1] —Continued

(Troy ounces)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Suriname | 823 | 599 | 482 | 322 | 500 |
| Sweden | [e]70,000 | 77,160 | 102,880 | 122,173 | 140,000 |
| Taiwan[5] | 56,695 | 71,770 | 52,361 | 37,794 | 30,600 |
| Tanzania[e] | 400 | 600 | 800 | 2,680 | 2,700 |
| U.S.S.R.[e] | 8,425,000 | 8,550,000 | 8,600,000 | 8,650,000 | 8,700,000 |
| United States | 1,379,161 | 1,465,686 | [r]2,002,526 | [r]2,084,615 | [3]2,475,436 |
| Venezuela | 27,810 | 27,993 | [e]33,200 | [r] [e]50,885 | 72,900 |
| Yugoslavia[5] | [r]115,164 | [r]135,451 | 136,255 | [e]140,000 | 145,000 |
| Zaire | [r]65,169 | [r]60,733 | 192,930 | 117,115 | 75,000 |
| Zambia | 10,545 | 13,439 | 10,160 | 12,185 | 11,600 |
| Zimbabwe | 371,000 | 426,000 | 453,373 | 478,306 | 480,000 |
| Total | [r]41,250,525 | [r]43,126,517 | 44,995,806 | 46,408,295 | 48,216,620 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through June 10, 1986.

[2] Gold is also produced in Bulgaria, Burma, Czechoslovakia, the German Democratic Republic, Guinea, Norway, Poland, Senegal, Thailand, and several other countries. However, available data are insufficient to make reliable output estimates.

[3] Reported figure.

[4] Officially reported figures are as follows, in troy ounces: Major mines: 1981—140,691; 1982—148,408; 1983—199,206; 1984—213,963; and 1985—not available. Small mines (garimpos): 1981—414,744; 1982—671,982; 1983—1,526,775; 1984—982,623; and 1985—not available.

[5] Refinery output.

[6] Excludes production from so-called "people's mines," but includes gold recovered as byproduct of copper mining.

[7] These figures are based on gold taxed for export and include gold entering Liberia undocumented from Guinea and Sierra Leone.

[8] Production series for Mexico revised since 1980 to reflect mine output data published for each State and municipality.

[9] Excludes estimates of gold produced in Sierra Leone, which is moved through undocumented channels for sale in Liberia.

## TECHNOLOGY

Research directed toward the recovery of gold and other precious metals from primary and secondary sources was continued by the Bureau of Mines in 1985. The Bureau reported on the application of particle agglomeration technology to finely ground precious-metals-bearing tailings. It concluded that decreased leaching time and improved precious metals recovery made the technology cost effective.[21]

A procedure for selectively extracting platinum-group metals and gold from flotation concentrate from the Stillwater Complex (Montana) was devised by the Bureau. The two-stage leaching scheme, employing roasting followed by several leaching steps, extracted up to 99% of the gold, 97% of the platinum, and 92% of the palladium from the roasted concentrate. Techniques for recovering the precious metals from the pregnant solution were addressed.[22]

Gold and silver are commonly recovered from cyanide solution either by chemical precipitation onto zinc dust (the Merrill-Crowe process) or by electrochemical deposition onto a cathode fashioned of stainless steel wool. Chemical methods of processing the precious-metals-bearing steel zinc precipitates and steel wool cathodes were investigated by the Bureau. Leaching-precipitation experiments performed on the cathodes and precipitates recovered 99.9% of the gold as a gold-bearing residue. Treatment of the residue produced gold precipitates that ranged in fineness from 997 to 999 fine. The method was said to provide a viable technique for the smaller operator to produce high-purity gold without using pyrometallurgical refining methods.[23]

Hydrometallurgical procedures for concentrating precious metals from a mechanically processed metal fraction of obsolete military electronic scrap were tested by the Bureau. Included was a three-step process evaluation study of mechanical processing of general electronic scrap and two hydrometallurgical procedures for leaching high-tension-separated metallic concentrates obtained from the mechanical processing step. Process evaluation concluded that only mechanical processing is economically viable.[24]

The application of microbiology to gold exploration and processing was featured in several reports. Research at the U.S. Geological Survey suggested that the anomalous presence of aerobic spore-forming bacilli of the *Bacillus Cereus* group in stream and soil sediments may be a sensitive indicator of several types of concealed mineral deposits, including vein-type gold deposits. Preliminary tests suggest that measurement of the relative populations of certain soil bacteria may prove to be a more sensitive exploration tool than conventional geochemical techniques.[25]

A report on the use of biological leaching to pretreat or dissolve pyrite and liberate contained gold discussed the successful operation of a continuous bioleach circuit applied to gold-bearing concentrate from Placer Development's Porgera deposit in Papua New Guinea. Bioleach residues were cyanide-leached to extract gold and silver values. The features and advantages of biological oxidation as a pretreatment for refractory precious metal ores and concentrates were discussed.[26] Another report, detailing recent developments in gold processing, including the bioxidation process referenced above, discussed how the Homestake gold mine at Lead, SD, recently began treating its cyanide-bearing process wastewater with a technique utilizing a subspecies of the bacterium *Pseudomonas*. The bacteria degrade cyanide and thiocyanide, thereby reducing the quantity of weak-acid-dissociable cyanide in wastewater discharges to less than 50 parts per billion.[27] Japanese researchers reportedly found that ultrafine particles of gold, observed using a special technique, appeared to change shape as gold atoms moved around on the surface of the particles. This change in shape was reportedly caused by the fact that all of the gold atoms comprising the ultrafine particles moved in a manner to form various crystalline structures.[28]

A new prototype gas chromatography detector, developed by Professor Robert E. Sievers, University of Colorado, employs a gold catalyst to detect some atmospheric pollutants heretofore not readily detectable. The new detector, known as the Redox Chemiluminescence Detector, was reportedly capable of detecting substances such as formaldehyde, carbon monoxide, formic acid, and many others. It may, in addition, provide a new way to synthesize a variety of oxidation products, such as compounds useful in manufacturing plastics.[29]

A 4-year study conducted by the Mineral Industry Research Laboratory, at the University of Alaska, resulted in the development of a radiotracer technique for evaluating the fine gold recovery characteristics and performance of gravity concentrators. In the technique, fine particles of native gold, those small enough to pass through a 40-mesh screen, were weakly activated in a nuclear reactor then introduced into experimental separation devices. Process water, upon exiting the separation device, was piped into a compound water cyclone where concentration and recovery of the fine gold not captured by earlier separators was performed. By using gamma radiation detectors to measure the progress of the radioactive particles through various recovery stages, researchers were able to rapidly evaluate the effectiveness of the recovery technique employed and avoid the time-consuming and relatively inaccurate sampling and assaying steps previously required.[30]

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[1] Physical scientist, Division of Nonferrous Metals.

[2] Ounce refers to troy ounce.

[3] Federal Register. V. 50, No. 192, Oct. 3, 1985, p. 40325.

[4] ———. Nonferrous Metals Manufacturing Point Source Category; Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards; Final Rule. V. 50, No. 183, Sept. 20, 1985, pp. 38276-38402.

[5] ———. Ore Mining and Dressing Point Source Category; Gold Placer Mining; Effluent Limitations Guidelines and New Source Performance Standards; Proposed Regulation. V. 50, No. 224, Nov. 20, 1985, pp. 47982-48015.

[6] State of Colorado. Senate Bill No. 94., Revised Statutes, Title 34, Sec. 32, Para. 110, 1985.

[7] State of Washington. State of Washington Laws, 1985. Chapter 471, Engrossed Substitute Senate Bill No. 4228, An Act Relating to Revenue and Taxation, Sec. 5, Paras. 1-3.

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[18] Values have been converted from South African rands (R) to U.S. dollars at the rate of R1.00 = US$0.4564 for 1985, as shown in Int. Financial Stat., v. 39, No. 5, May 1986, p. 436.

[19] Published by Marketing Services Department, International Services Department, International Gold Corp. Ltd. Gold and South African Gold Mines. P.O. Box 61897, 2107 Marshalltown, Johannesburg, Republic of South Africa. July 1985, 107 pp.

[20] Work cited in footnote 12.

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# Graphite

## By Harold A. Taylor, Jr.[1]

No domestic amorphous graphite material was mined in 1985. All natural graphites, including crystalline flake, were in more than adequate supply as demand by industrial users tapered off from the previous year. Prices of the major imported graphites generally increased from those of 1984, except for the price of Sri Lankan graphite, which dropped 26%.

Production of manufactured graphite decreased 6% to 246,000 short tons valued at $628 million. Production of graphite fibers increased 38% to 1,902 tons valued at $112 million.

**Domestic Data Coverage.**—Domestic production data for synthetic graphite are developed by the Bureau of Mines from a voluntary survey of domestic producers, titled "Synthetic Graphite." Of the 38 operations to which a survey request was sent, 97% responded, representing 100% of the total production data shown in table 4 since the 2 nonrespondents were not included.

**Table 1.—Salient natural graphite statistics**

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production ______ short tons__ | -- | W | W | W | -- |
| Apparent consumption[1] ______ do____ | 54,315 | W | W | W | 42,578 |
| Exports ______ do____ | 11,344 | 10,335 | 9,435 | 7,096 | 10,159 |
| Value ______ thousands__ | $4,433 | $4,099 | $3,455 | $2,807 | $3,830 |
| Imports for consumption[1] ______ short tons__ | 65,659 | 53,150 | 43,586 | 58,246 | 52,737 |
| Value[1] ______ thousands__ | $19,093 | $15,676 | $11,921 | $14,579 | $16,186 |
| World: Production ______ short tons__ | [r]649,093 | [r]619,928 | 664,029 | [p]685,507 | [e]676,740 |

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data.

[1] Data do not include artificial graphite.

**Legislation and Government Programs.**—There were no acquisitions or disposals of strategic graphite in 1985.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. Substantial changes were proposed for the graphite goals: 13,996 tons of Madagascar crystalline flake, 5,059 tons of Sri Lankan amorphous lump, and 2,237 tons of crystalline graphite other than Madagascar and Sri Lanka would be in tier I, and 415 tons of Sri Lankan amorphous lump would be in tier II. Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

Production of graphite fibers made from pitch was considered for funding under title 3 of the Defense Production Act. The funding would be used for purchase guarantees for domestically produced graphite fiber made from pitch, or possibly for manufacturing technology or industrial modernization.

Table 2.—U.S. Government stockpile goals and yearend stocks of natural graphite in 1985, by type

(Short tons)

| Type | Goal | National stockpile inventory |
|---|---|---|
| Madagascar crystalline flake | 20,000 | 17,829 |
| Sri Lanka amorphous lump | 6,300 | 5,444 |
| Crystalline, other than Madagascar and Sri Lanka | 2,800 | 1,933 |
| Nonstockpile-grade, all types | -- | 932 |

Source: General Services Administration. Inventory of Stockpile Materials as of Dec. 31, 1985.

## DOMESTIC PRODUCTION

United Minerals Co. began producing sizable amounts of low-grade amorphous graphitic material by open pit mining from the claims of National Minerals Corp. near Townsend, MT, in 1982. Production had been tapering off, and ceased in 1985. Graphite Sales Inc. continued to make the material available. Other domestic deposits of graphite received little or no attention.

Output of manufactured graphite decreased 6% to about 246,000 tons, at 35 plants, with a likelihood of some unreported production for in-house use.

Production of all kinds of graphite fiber and cloth increased 38% to 1,902 tons.

Table 3.—Principal producers of manufactured graphite in 1985

| Company | Plant location | Product[1] |
|---|---|---|
| Airco Carbon, a division of Airco Inc | Niagara Falls, NY | Anodes, electrodes, crucibles, motor brushes, refractories, unmachined shapes, powder. |
| Do | Punxsutawney, PA | |
| Do | St. Marys, PA | |
| Do | Ridgeville, SC | |
| Ashland Petroleum Co., Carbon Fibers Div | Ashland, KY | High-modulus fibers. |
| Avco Corp., Avco Specialty Materials Div | Lowell, MA | Do. |
| The Carborundum Co., Graphite Products Div. | Sanborn, NY | Motor brushes, unmachined shapes, cloth. |
| CCF Inc., Research Lab | Summit, NJ | High-modulus fibers. |
| Do | Rock Hill, SC | |
| Fiber Materials Inc | Biddeford, ME | High-modulus fibers and cloth. |
| Fiber Technology Corp | Provo, UT | |
| BF Goodrich Co., Engineered Systems Div., Super Temp Operation. | Santa Fe Springs, CA | Other. |
| Great Lakes Carbon Corp | Rockwood, TN | Anodes, electrodes, high-modulus fibers, unmachined shapes, other. |
| Do | Morganton, NC | |
| Do | Niagara Falls, NY | |
| Do | Ozark, AR | |
| Hercules Inc | Salt Lake City, UT | High-modulus fibers. |
| HITCO Materials Group, Owens-Corning Fiberglas Corp. | Gardena, CA | Cloth and high-modulus fibers. |
| Hysol Grafil Co | Sacramento, CA | High-modulus fibers. |
| Ohio Carbon Co | Cleveland, OH | Electric motor brushes, unmachined shapes. |
| Pfizer Minerals, Pigments & Metals Div | Easton, PA | Other. |
| Polycarbon Inc | North Hollywood, CA | Cloth. |
| Sigri Carbon Corp | Hickman, KY | Electrodes and other. |
| The Stackpole Corp., Carbon Div | Lowell, MA | High-modulus fibers, motor brushes, unmachined shapes, refractories, powder. |
| Do | St. Marys, PA | |
| Superior Graphite Co | Russellville, AR | Electrodes and other. |
| Do | Hopkinsville, KY | |
| Ultra Carbon | Bay City, MI | Other. |
| Union Carbide Corp., Carbon Products Div | Clarksburg, WV | Anodes, electrodes, unmachined shapes, motor brushes, powder, cloth, high-modulus fibers, other. |
| Do | Clarksville, TN | |
| Do | Columbia, TN | |
| Do | Fostoria, OH | |
| Do | Greenville, SC | |
| Do | Niagara Falls, NY | |
| Do | Yabucoa, PR | |

[1] Cloth includes low-modulus fibers; electric motor brushes include machined shapes; crucibles include vessels.

## Table 4.—U.S. production of manufactured graphite, by use

| Use | 1984 Quantity (short tons) | 1984 Value (thousands) | 1985 Quantity (short tons) | 1985 Value (thousands) |
|---|---|---|---|---|
| Synthetic graphite products: | | | | |
| Anodes | 4,680 | $14,133 | 7,021 | $19,813 |
| Cloth and fibers (low-modulus) | 223 | 17,979 | 316 | 27,235 |
| Crucibles, vessels, refractories | W | W | W | W |
| Electric motor brushes and machined shapes | W | W | W | W |
| Electrodes | 177,116 | 398,180 | 164,578 | 348,812 |
| Graphite articles | – | 39,895 | – – | 36,365 |
| High-modulus fibers | [r]1,160 | [r]56,436 | 1,586 | 84,743 |
| Unmachined graphite shapes | [r]12,848 | [r]59,001 | 11,875 | 66,069 |
| Other | [r]37,290 | [r]36,235 | 38,900 | 38,690 |
| Total | [r]233,317 | [r]621,859 | 224,276 | 621,727 |
| Synthetic graphite powder and scrap | 29,911 | 6,668 | 22,100 | 5,970 |
| Grand total | [r]263,228 | [r]628,527 | 246,376 | [1]627,696 |

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1]Data do not add to total shown because of independent rounding.

## Table 5.—U.S. production of graphite fibers

| Year | Cloth and low-modulus fibers | | High-modulus fibers | | Total | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1975 | 154 | $10,600 | 52 | $4,690 | 206 | $15,290 |
| 1976 | 163 | 11,376 | 37 | 3,870 | 200 | 15,246 |
| 1977 | 136 | 8,800 | 49 | 4,330 | 185 | 13,130 |
| 1978 | 141 | 8,720 | 149 | 11,804 | 290 | 20,524 |
| 1979 | 169 | 10,089 | 194 | 13,031 | 363 | 23,120 |
| 1980 | 169 | 11,254 | 306 | 17,379 | 475 | 28,633 |
| 1981 | 216 | 15,293 | 409 | 21,759 | 625 | 37,052 |
| 1982 | 212 | 17,706 | 605 | 30,091 | 817 | 47,797 |
| 1983 | 188 | 14,217 | 739 | 33,854 | 927 | 48,071 |
| 1984 | 223 | 17,979 | [r]1,160 | [r]56,436 | [r]1,383 | [r]74,415 |
| 1985 | 316 | 27,235 | 1,586 | 84,743 | 1,902 | 111,978 |

[r]Revised.

There were a number of changes in ownership in the graphite industry, particularly among the graphite fiber producers. Horsehead Industries Inc. purchased Great Lakes Carbon Corp. BASF America Corp. purchased the Celanese Corp. graphite fiber operations and two subsidiaries that produce graphite fiber composite items for $135 million; the firm already makes the resins for the composites in Europe. Armco Inc. sold Owens-Corning Fiberglas Corp. its graphite fiber subsidiary, HITCO Materials Group, and two other high technology materials subsidiaries for $415 million. In December, Union Carbide Corp. announced plans to sell its graphite fiber operations to Amoco Minerals Co. in 1986. E. I. du Pont de Nemours & Co. Inc. was planning to enter the graphite fiber business with a pitch-based fiber based on Conoco Inc. technology. In 1985, the company purchased the graphite fiber research facilities and composite production operations of Exxon Corp.

Ashland Petroleum Co. announced plans to expand its plant at Catlettsburg, KY, from a capacity of 30 to 100 tons per year of pitch-based fiber.

A new trade association called Suppliers of Advanced Composite Materials Association (SACMA) was formed for graphite fiber and composite producing firms. SACMA expects to be active in standardizing test methods, compiling industry statistics, and dealing with issues related to the Export Control Act.

## CONSUMPTION AND USES

Reported consumption of natural graphite decreased slightly to about 34,700 tons. The three major uses of natural graphite—refractories, foundries, and brake linings—accounted for 48% of reported consumption, compared with 61% in 1984.

Graphite fiber-reinforced, lightweight, concrete building panels have been developed in Japan. The panels are only one-third the weight of ordinary ones, which saves time and expense when handling them and allows a lighter structural steel frame to be used in the building. However, making the concrete for the panels is an exacting process, requiring the concrete to be vibrated rather than stirred.

A bonded carbon fiber material, Calcarb, was produced and sold by Consarc Engineering Ltd. of the United Kingdom for consumption as vacuum furnace insulation. The material can be made in many different forms, including boards and cylindrical sleeves. It is made by mixing 1/16-inch-long byproduct rayon fiber with a phenolic resin-water slurry, and heating the slurry to 900° C to convert the fiber to carbon. Advantages of Calcarb are its low thermal conductivity and expansion and great mechanical strength. Porous electrodes, catalyst supports, filters for fluids and molten metals, and aerospace applications were being examined as potential new markets for Calcarb.

**Table 6.—U.S. consumption of natural graphite, by use**

| Use | Crystalline | | Amorphous[1] | | Total[2] | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1984: | | | | | | |
| Batteries | W | W | W | W | 931 | $1,563 |
| Brake linings | 1,156 | $1,045 | 2,869 | $2,496 | 4,025 | 3,541 |
| Carbon products[3] | 316 | 660 | 249 | 328 | 565 | 988 |
| Crucibles, retorts, stoppers, sleeves, nozzles | 1,953 | 1,858 | ([4]) | 6 | 1,953 | 1,864 |
| Foundries[5] | 2,337 | 1,285 | 4,804 | 1,810 | 7,141 | 3,095 |
| Lubricants[6] | 1,170 | 1,763 | 1,365 | 1,216 | 2,535 | 2,979 |
| Pencils | 1,557 | 2,121 | 356 | 257 | 1,913 | 2,378 |
| Powdered metals | 363 | 567 | 196 | 356 | 559 | 923 |
| Refractories | W | W | W | W | 10,461 | 4,200 |
| Rubber | 184 | 211 | 232 | 140 | 416 | 351 |
| Steelmaking | 326 | 142 | 1,739 | 798 | 2,065 | 940 |
| Other[7] | 299 | 498 | 2,306 | 2,123 | 2,605 | 2,621 |
| Withheld uses | 2,472 | 3,523 | 8,920 | 2,240 | -- | -- |
| Total[2] | 12,135 | 13,674 | 23,037 | 11,769 | 35,172 | 25,443 |
| 1985: | | | | | | |
| Batteries | W | W | W | W | 1,569 | 2,602 |
| Brake linings | 1,023 | 960 | 2,448 | 2,297 | 3,472 | 3,257 |
| Carbon products[3] | 379 | 843 | 206 | 173 | 585 | 1,016 |
| Crucibles, retorts, stoppers, sleeves, nozzles | 4,213 | 3,529 | 1 | 15 | 4,215 | 3,544 |
| Foundries[5] | 514 | 612 | 6,006 | 1,953 | 6,520 | 2,565 |
| Lubricants [6] | 1,025 | 1,478 | 2,586 | 2,327 | 3,611 | 3,805 |
| Pencils | 1,829 | 2,737 | 339 | 231 | 2,168 | 2,968 |
| Powdered metals | 348 | 520 | 226 | 451 | 574 | 971 |
| Refractories | W | W | W | W | 6,503 | 3,257 |
| Rubber | 217 | 249 | 289 | 170 | 506 | 419 |
| Steelmaking | 131 | 81 | 1,836 | 691 | 1,967 | 772 |
| Other[7] | 227 | 295 | 2,741 | 2,815 | 2,968 | 3,110 |
| Withheld uses | 3,216 | 4,342 | 4,855 | 1,517 | -- | -- |
| Total[2] | 13,123 | 15,647 | 21,534 | 12,641 | 34,657 | 28,288 |

W Withheld to avoid disclosing company proprietary data; included with "Withheld uses."

[1] Includes mixtures of natural and manufactured graphite.

[2] Data may not add to totals shown because of independent rounding.

[3] Includes bearings and carbon brushes.

[4] Less than 1/2 unit.

[5] Includes foundry facings.

[6] Includes ammunition, packings, and seed coating.

[7] Includes paints and polishes, antiknock and other compounds, soldering and/or weld, electrical and electronic products, mechanical products, magnetic tape, small packages, industrial diamonds, and drilling mud.

While electric arc steelmaking capacity has continued to grow worldwide, graphite electrode consumption has not kept pace because of technological advances in electrode construction. The shrinking market for electrodes has led Union Carbide Corp. to suspend production at its new plant at Clarksville, TN. In addition, the Airco Carbon Div. of BOC Inc. shifted most of its production from its old plant in Pennsylvania to its new plant at Ridgeville, SC. While Great Lakes Carbon Corp. has kept all of its plants going except for a small one in California, the present electrode market has resulted in the shelving of expansion plans at its two newest plants.[2]

## PRICES

Graphite prices are often negotiated between the buyer and seller, and are based on purity and other criteria. Therefore, published price quotations are given as a range of prices. Another source of information for graphite prices is the average customs value per ton of the different imported classes. However, it should be noted that these mainly represent shipments of unprocessed graphite.

The average prices of crystalline flake and other natural graphite imports were little changed in 1985, while the prices of other types dropped or rose significantly from those of 1984. The prices of crystalline flake increased by 5% to $536 per ton; Mexican amorphous graphite rose by 25% to $50 per ton; all types of Sri Lankan lump graphite dropped by 26% to $790 per ton; and other natural graphite (mostly fine crystalline flake and dust) dropped by 5% to $441 per ton.

Average prices for natural graphite at the point of consumption changed slightly in 1985. The price for crystalline graphite (mostly crystalline flake, some crystalline dust, and a little lump graphite) was $1,192 per ton, up 6% from that of 1984. The price for amorphous graphite (including small amounts of amorphous-synthetic graphite mixtures) was $587 per ton, up 15% from that of 1984.

**Table 7.—Representative yearend graphite prices[1]**

(Per short ton)

| | 1984 | 1985 |
|---|---|---|
| Flake and crystalline graphite, bags: | | |
| China | $54-$1,542 | $54-$1,542 |
| Germany, Federal Republic of | 286- 3,084 | 227- 3,357 |
| Madagascar | 227- 726 | 227- 816 |
| Norway | 181- 816 | -- -- |
| Sri Lanka | 272- 1,361 | 272- 1,361 |
| Amorphous, nonflake, cryptocrystalline graphite (80% to 85% carbon): | | |
| Korea, Republic of (bags) | 82- 109 | 82- 113 |
| Mexico (bulk) | 64- 109 | 82- 109 |

[1] F.o.b. foreign port or border.

Source: Engineering and Mining Journal. V. 185, No. 12, Dec. 1984, p. 27., and v. 186, No. 12, Dec. 1985, p. 11.

## FOREIGN TRADE

Exports of both natural and artificial graphite increased by 71%. Exports of graphite electrodes totaled 58,675 tons worth $88.1 million, of which 10,275 tons ($15.2 million) went to Canada, 7,210 tons ($10.0 million) to Venezuela, 5,443 tons ($5.2 million) to Norway, 5,117 tons ($9.9 million) to Brazil, 4,574 tons ($7.4 million) to the U.S.S.R., and the balance to other destinations.

Imports of natural graphite decreased 9% to 52,737 tons. Imports of natural graphite from Brazil and Sri Lanka gained by 153% and 85% respectively, while imports from Canada and Mexico dropped sharply to about the 1983 levels.

## Table 8.—U.S. exports of natural and artificial graphite, by country

| Country | Natural[1] |  | Artificial |  | Total |  |
|---|---|---|---|---|---|---|
|  | Quantity (short tons) | Value | Quantity (short tons) | Value | Quantity (short tons) | Value |
| 1984: |  |  |  |  |  |  |
| Brazil | 16 | $4,896 | 153 | $96,107 | 169 | $101,003 |
| Canada | 3,490 | 1,162,208 | 1,725 | 643,558 | 5,215 | 1,805,766 |
| Germany, Federal Republic of | 103 | 39,307 | 147 | 59,853 | 250 | 99,160 |
| Italy | 16 | 9,402 | 21 | 20,134 | 37 | 29,536 |
| Japan | 201 | 262,934 | 529 | 742,514 | 730 | 1,005,448 |
| Mexico | 1,972 | 612,157 | 271 | 116,148 | 2,243 | 728,305 |
| United Kingdom | 252 | 136,464 | 155 | 111,990 | 407 | 248,454 |
| Venezuela | 301 | 177,294 | 36 | 37,102 | 337 | 214,396 |
| Other | [r]745 | [r]402,779 | [r]1,189 | [r]958,809 | [r]1,934 | [r]1,361,588 |
| Total | 7,096 | 2,807,441 | 4,226 | 2,786,215 | 11,322 | 5,593,656 |
| 1985: |  |  |  |  |  |  |
| Brazil | 49 | 22,879 | 783 | 992,413 | 832 | 1,015,292 |
| Canada | 4,065 | 1,366,750 | 1,240 | 592,536 | 5,305 | 1,959,286 |
| Germany, Federal Republic of | 2,002 | 711,818 | 707 | 319,315 | 2,709 | 1,031,133 |
| Italy | 1,174 | 205,953 | 164 | 91,765 | 1,338 | 297,718 |
| Japan | 226 | 318,799 | 2,671 | 800,694 | 2,897 | 1,119,493 |
| Mexico | 1,115 | 395,995 | 1,964 | 194,699 | 3,079 | 590,694 |
| United Kingdom | 212 | 133,984 | 186 | 141,121 | 398 | 275,105 |
| Venezuela | 241 | 152,561 | 98 | 74,390 | 339 | 226,951 |
| Other | 1,075 | 520,838 | 1,339 | 898,868 | 2,414 | 1,419,706 |
| Total | 10,159 | 3,829,577 | 9,152 | 4,105,801 | 19,311 | 7,935,378 |

[r] Revised.

[1] Amorphous, crystalline flake, lump or chip, and natural, not elsewhere classified.

Source: Bureau of the Census.

## Table 9.—U.S. imports for consumption of natural graphite, by country

| Country | Crystalline flake |  | Lump or chippy dust |  | Other natural crude and refined |  | Amorphous |  | Total[1] |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1983 | 7,034 | $3,866 | 751 | $870 | 10,124 | $5,711 | 25,677 | $1,474 | [2]43,586 | [2]$11,921 |
| 1984: |  |  |  |  |  |  |  |  |  |  |
| Austria | -- | -- | -- | -- | -- | -- | 32 | 7 | 32 | 7 |
| Belgium-Luxembourg | 1 | 2 | -- | -- | -- | -- | -- | -- | 1 | 2 |
| Brazil | 2,203 | 1,492 | -- | -- | 513 | 238 | -- | -- | 2,716 | 1,730 |
| Canada | 2,116 | 1,068 | -- | -- | 412 | 263 | -- | -- | 2,528 | 1,331 |
| China | 4,602 | 1,812 | -- | -- | 4,829 | 1,665 | 5,801 | 284 | 15,232 | 3,761 |
| Denmark | -- | -- | -- | -- | ([3]) | 2 | -- | -- | ([3]) | 2 |
| France | 362 | 213 | -- | -- | 80 | 45 | -- | -- | 442 | 258 |
| Gambia | 220 | 83 | -- | -- | -- | -- | -- | -- | 220 | 83 |
| Germany, Federal Republic of | 20 | 62 | -- | -- | 840 | 691 | -- | -- | 860 | 753 |
| Hong Kong | -- | -- | -- | -- | 897 | 214 | -- | -- | 897 | 214 |
| India | 77 | 38 | -- | -- | 332 | 211 | -- | -- | 409 | 249 |
| Italy | -- | -- | -- | -- | 1 | 6 | -- | -- | 1 | 6 |
| Japan | 182 | 131 | -- | -- | 273 | 291 | -- | -- | 455 | 422 |
| Korea, Republic of | -- | -- | -- | -- | -- | -- | 53 | 12 | 53 | 12 |
| Madagascar | 828 | 481 | -- | -- | 2,173 | 977 | -- | -- | 3,001 | 1,458 |
| Mexico | -- | -- | -- | -- | 1,943 | 995 | 25,922 | 1,025 | 27,865 | 2,020 |
| Netherlands | ([3]) | ([3]) | -- | -- | 3 | 1 | -- | -- | 3 | 1 |
| Norway | 4 | 7 | -- | -- | 150 | 61 | -- | -- | 154 | 68 |
| Seychelles | -- | -- | -- | -- | 9 | 16 | -- | -- | 9 | 16 |
| Singapore | -- | -- | -- | -- | 34 | 17 | -- | -- | 34 | 17 |
| South Africa, Republic of | -- | -- | -- | -- | 1,200 | 645 | -- | -- | 1,200 | 645 |
| Sri Lanka | -- | -- | 892 | 950 | -- | -- | -- | -- | 892 | 950 |
| Sweden | -- | -- | -- | -- | 28 | 59 | -- | -- | 28 | 59 |
| Switzerland | -- | -- | -- | -- | 3 | 5 | -- | -- | 3 | 5 |
| Taiwan | -- | -- | -- | -- | 901 | 268 | -- | -- | 901 | 268 |
| United Kingdom | 105 | 66 | -- | -- | 122 | 106 | -- | -- | 227 | 172 |
| Zimbabwe | -- | -- | -- | -- | 80 | 73 | -- | -- | 80 | 73 |
| Total[1] | 10,720 | 5,455 | 892 | 950 | 14,823 | 6,849 | 31,808 | 1,329 | [2]58,246 | [2]14,579 |

See footnotes at end of table.

Table 9.—U.S. imports for consumption of natural graphite, by country —Continued

| Country | Crystalline flake |  | Lump or chippy dust |  | Other natural crude and refined |  | Amorphous |  | Total[1] |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1985: |  |  |  |  |  |  |  |  |  |  |
| Antigua | -- | -- | -- | -- | 19 | $8 | -- | -- | 19 | $8 |
| Belgium-Luxembourg | -- | -- | -- | -- | 14 | 22 | -- | -- | 14 | 22 |
| Brazil | 1,775 | $1,081 | -- | -- | 5,092 | 2,002 | -- | -- | 6,867 | 3,083 |
| Canada | 114 | 58 | -- | -- | 340 | 140 | -- | -- | 454 | 198 |
| China | 2,480 | 1,054 | -- | -- | 10,851 | 3,427 | 1,084 | $74 | 14,415 | 4,555 |
| France | -- | -- | -- | -- | 110 | 103 | -- | -- | 110 | 103 |
| Germany, Federal Republic of | 48 | 25 | -- | -- | 907 | 934 | -- | -- | 955 | 959 |
| Hong Kong | 40 | 4 | -- | -- | 932 | 168 | 212 | 19 | 1,184 | 191 |
| India | 140 | 72 | -- | -- | 430 | 325 | -- | -- | 570 | 397 |
| Japan | 62 | 144 | -- | -- | 190 | 363 | -- | -- | 252 | 507 |
| Liberia | -- | -- | -- | -- | 33 | 42 | -- | -- | 33 | 42 |
| Macao | 19 | 12 | -- | -- | -- | -- | -- | -- | 19 | 12 |
| Madagascar | 1,169 | 675 | -- | -- | 1,819 | 1,405 | -- | -- | 2,988 | 2,080 |
| Mexico | -- | -- | -- | -- | 2,118 | 1,053 | 19,736 | 980 | 21,854 | 2,033 |
| Netherlands | -- | -- | -- | -- | 222 | 135 | -- | -- | 222 | 135 |
| Norway | 8 | 1 | -- | -- | 37 | 19 | -- | -- | 45 | 20 |
| Sierra Leone | -- | -- | -- | -- | 17 | 21 | -- | -- | 17 | 21 |
| South Africa, Republic of | -- | -- | -- | -- | 524 | 251 | -- | -- | 524 | 251 |
| Sri Lanka | -- | -- | 1,654 | $1,307 | -- | -- | -- | -- | 1,654 | 1,307 |
| Sweden | 4 | 8 | -- | -- | -- | -- | -- | -- | 4 | 8 |
| Switzerland | -- | -- | -- | -- | 38 | 11 | -- | -- | 38 | 11 |
| Taiwan | -- | -- | -- | -- | 282 | 93 | -- | -- | 282 | 93 |
| United Kingdom | 40 | 25 | -- | -- | (3) | 16 | -- | -- | 40 | 41 |
| Zimbabwe | -- | -- | -- | -- | 175 | 108 | -- | -- | 175 | 108 |
| Total[1] | 5,899 | 3,161 | 1,654 | 1,307 | 24,152 | 10,646 | 21,032 | 1,078 | [2]52,737 | [2]16,186 |

[1] Data may not add to totals shown because of independent rounding.
[2] Data do not include artificial graphite.
[3] Less than 1/2 unit.

Source: Bureau of the Census.

The United States has the world's largest capacity for fabricating graphite fiber into composites and was the world's leading consumer and producer of all kinds of fiber-reinforced materials in 1985. However, the United States was much less dominant in the production of the graphite fiber consumed as a raw material to make the composites. The domestic graphite fiber capacity was about two-thirds of the Japanese capacity in 1982. Most of the polyacrylonitrile precursor used to make domestic graphite fiber (with the exception of fairly small amounts of fiber made from other materials) is now imported from Japan, although this is changing to some degree.

A U.S. Government study concluded that not only will the United States continue to encounter competition from Japan as it does now, but that it will encounter competition in graphite fiber from other foreign producers, mostly the Federal Republic of Germany and the United Kingdom. Japanese competition will broaden into fabricating the final materials. The authors expect that the United States and Japan will dominate world markets for graphite fiber during the 1990's although they will encounter increasing competition from European producers.[8]

**Table 10.—U.S. imports for consumption of artificial graphite and graphite electrodes, by country**

| Country | Artificial graphite |  | Graphite electrodes |  |
|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1984: |  |  |  |  |
| Australia | (1) | $25 | (1) | $16 |
| Belgium | (1) | 27 | 998 | 1,915 |
| Brazil | -- | -- | 116 | 29 |
| Canada | 995 | 239 | 3,801 | 4,188 |
| China | 467 | 625 | 557 | 900 |
| France | 270 | 350 | 8,096 | 7,061 |
| Germany, Federal Republic of | 3,670 | 564 | 2,409 | 4,212 |
| Israel | -- | -- | 20 | 30 |
| Italy | -- | -- | 8,551 | 10,598 |
| Japan | 443 | 3,065 | 37,704 | 64,092 |
| Mexico | -- | -- | 15 | 15 |
| Netherlands | 7 | 110 | 6,164 | 2,021 |
| Norway | -- | -- | 42 | 10 |
| Singapore | 247 | 350 | 852 | 1,177 |
| Spain | -- | -- | 74 | 115 |
| Sweden | -- | -- | 54 | 27 |
| Switzerland | 4,332 | 6,454 | 269 | 233 |
| Taiwan | 1 | 9 | 20 | 60 |
| United Kingdom | 23 | 89 | 2,244 | 2,021 |
| Other | -- | -- | 2 | 15 |
| Total[2] | 10,456 | 11,906 | 71,988 | 98,735 |
| 1985: |  |  |  |  |
| Australia | 3 | 29 | -- | -- |
| Austria | -- | -- | 22 | 50 |
| Belgium | 13 | 50 | 1,404 | 2,719 |
| Cameroon | 20 | 29 | -- | -- |
| Canada | 1,117 | 422 | 2,625 | 3,770 |
| China | 211 | 278 | 153 | 230 |
| France | 454 | 575 | 2,946 | 4,640 |
| Germany, Federal Republic of | 906 | 2,217 | 6,730 | 8,780 |
| India | 212 | 226 | -- | -- |
| Israel | -- | -- | 20 | 44 |
| Italy | 53 | 102 | 3,386 | 4,989 |
| Jamaica | 5 | 33 | -- | -- |
| Japan | 964 | 5,200 | 36,736 | 64,752 |
| Korea, Republic of | -- | -- | 11 | 46 |
| Netherlands | 23 | 113 | 1,642 | 2,167 |
| Singapore | -- | -- | 1,473 | 2,195 |
| South Africa, Republic of | 2 | 13 | 1 | 2 |
| Spain | -- | -- | 7 | 10 |
| Sweden | 4 | 12 | (1) | 68 |
| Switzerland | 3,137 | 4,007 | 4,144 | 1,231 |
| Taiwan | 2 | 7 | 65 | 120 |
| United Kingdom | 118 | 535 | 931 | 1,097 |
| Total[2] | 7,241 | 13,847 | 62,296 | 96,913 |

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

World demand and world supply of graphite were about the same as those of 1984. China announced the discovery of a very large graphite deposit, and the major graphite mine in Norway was closed because of a fire.

**China.**—Chinese sources announced that the largest graphite deposit discovered so far has been found in eastern Heilongjiang Province. It consists of 10 beds, each about 5,000 feet long, 1,000 feet thick, and 150 feet wide. Reserves were estimated to be 680 million tons averaging 12% carbon. Although Chinese sources did not specify the type of graphite, it was believed to be amorphous. The deposit can be accessed easily by roads and utilities. The local government decided to invite foreign tenders for development of the deposit. Some crystalline flake deposits have been discovered on the island of Hainan; preliminary investigation indicated that reserves were about 5.5 million tons averaging 3.7% carbon with a rate of recovery over 90%.

**Finland.**—Information on graphite mining and usage in Finland appeared in 1985, for the first time. What is called "energy graphite" in Finnish has been found in three different regions of Finland. About 20% graphite must be present to maintain combustion; it is burned in special fluidized bed boilers.

**Germany, Federal Republic of.**—Sigri GmbH announced the commissioning of a 1,100-ton-per-year-capacity graphite fiber plant based on polyacrylonitrile as a raw material.

Graphitwerk Kropfmuehl AG, the only West German miner of crystalline flake graphite, produced 18,700 tons of product at its Kropfmuehl plant and 8,800 tons of product at its Werk Wedel plant in 1984, of which 45% was exported. About one-half of its domestic sales were to the refractories industry for use in crucibles, continuous casting ware, and carbon-magnesite bricks. About one-third to one-half of the firm's raw material was mined domestically at Kropfmuehl, the balance coming from its mine in Zimbabwe.[4]

**Japan.**—Mitsubishi Chemical Industries Ltd. began building a 550-ton-per-year-capacity graphite fiber plant at Sakoide, Kagawa Prefecture, that will come onstream in late 1986. This supersedes earlier plans for a 1,100-ton-per-year-capacity plant. The plant will cost $10 million and use coal tar, which the firm produces, as a raw material. The graphite fiber was expected to be lower in cost than polyacrylonitrile-based graphite fiber. The firm also announced plans to develop graphite fiber composites.

The rapid growth of electric arc steelmaking in Japan, and therefore Japanese consumption of graphite electrodes, appeared to be coming to a halt. Accounting for a sizable fraction of Japan's total production, 28% in 1984, electric arc steelmaking will have trouble expanding further when the rest of the industry is in severe overcapacity and with increasing foreign competition from neighboring countries. The Ministry of International Trade and Industry has been pressing hard for a reduction in electric arc steelmaking capacity, with minimal industry response so far.[5]

**Table 11.—Graphite: World production, by country[1]**

(Short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina | 2 | 13 | 22 | 16 | 20 |
| Austria | 26,243 | 26,953 | 44,553 | 48,269 | 44,000 |
| Brazil (marketable)[3] | 19,289 | 16,990 | 30,463 | 36,023 | 36,000 |
| Burma[4] | 1,568 | 308 | 220 | 258 | 220 |
| China[e] | 203,000 | 204,000 | 204,000 | 204,000 | 204,000 |
| Czechoslovakia[e] | [r]55,000 | [r]55,000 | [r]55,000 | [r]55,000 | 65,000 |
| Germany, Federal Republic of | [5]9,024 | [5]12,845 | 11,023 | 13,228 | 12,000 |
| India (mine)[6] | 80,240 | 57,735 | 43,615 | 42,975 | 44,000 |
| Italy | 3,897 | 3,538 | 2,534 | -- | -- |
| Korea, North[e] | 28,000 | 28,000 | 28,000 | 28,000 | 28,000 |
| Korea, Republic of: | | | | | |
| Amorphous | 37,533 | 29,033 | 35,903 | 62,014 | 55,000 |
| Crystalline flake | 928 | 691 | 766 | 2,541 | 2,200 |
| Madagascar | 14,698 | [r]16,766 | 14,944 | 15,403 | 15,500 |
| Mexico: | | | | | |
| Amorphous | 45,351 | 37,886 | 47,034 | 43,923 | 44,000 |
| Crystalline flake | 1,270 | 1,989 | 1,828 | 1,855 | 1,900 |
| Norway | 9,552 | 8,213 | 8,888 | 10,508 | 2,500 |
| Romania[e] | 13,800 | 13,800 | 13,900 | 13,700 | 13,200 |
| Sri Lanka | 8,348 | 9,704 | 6,094 | 6,198 | 6,000 |
| Thailand | 1,984 | 694 | 95 | (7) | -- |
| Turkey | NA | 3,704 | 5,297 | (8) | NA |
| U.S.S.R.[e] | 77,000 | 83,000 | 88,000 | 88,000 | 90,000 |
| United States | -- | W | W | W | -- |
| Zimbabwe | 12,366 | 9,066 | 21,850 | 13,596 | 13,200 |
| Total | [r]649,093 | [r]619,928 | 664,029 | 685,507 | 676,740 |

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1] Table includes data available through May 20, 1986.

[2] In addition to the countries listed, Namibia may have produced graphite during the period covered by this table, but output is unreported, and available general information is inadequate for formulation of reliable estimates of output levels.

[3] Does not include the following quantities sold directly without beneficiation, in short tons: 1981—17,988; 1982—6,758; 1983—12,278; 1984—2,902; and 1985—5,500 (estimated).

[4] Data are for fiscal year beginning Apr. 1 of that stated.

[5] Data presented represent estimated marketable product derived from raw graphite mined indigenously, assuming that marketable output equals one-half of officially reported raw graphite production.

[6] Indian marketable production is about 10% to 20% of mine production.

[7] Revised to zero.

[8] Revised to not available.

**Norway.**—On April 4, the processing plant of A/S Skaland Grafitverk was destroyed by a fire. The mine and warehousing area were unaffected. The firm continued its drilling and exploration program in the area and may move the mine a short distance for better access to the remaining ore. The firm tentatively has decided to build a new plant, which will be able to fabricate a much wider variety of products, including some high-purity, 99%-carbon product.

**Spain.**—The Government announced plans to set up a joint venture, Desarrollo de Nuevos Materiales, with the private sector, to develop and produce aramid and graphite fibers and fiber-reinforced composite materials.

**Sri Lanka.**—The Sri Lanka State Mining and Mineral Development Corp. and the Moriroko Co. Ltd. of Japan were negotiating an agreement to rehabilitate and work two abandoned graphite mines, one at Pussehena and one at Sigambalptitya.

## TECHNOLOGY

A review of the development of graphite fiber composite technology indicates that fabrication has become simpler and less expensive. There has been a fivefold reduction in cost for many graphite fibers over the last decade, and an average drop in cost of fiber to one-half its former level in the same period. Although the bulk of composite structures and parts for aerospace uses are now made using prepreg tape and hand layup, production is expected to incorporate less labor-intensive, lower cost techniques such as automated material placement, filament winding, pultrusion, and thermoforming. Newly sophisticated aerospace requirements reportedly are going to lead to higher performance fiber and resin systems to improve the damage tolerance of composites, for example, such fiber forms as 2-D and 3-D woven fabrics and braided structural subelements.[6]

When toxicological, epidemiological, and environmental sampling data on graphite fibers were examined along with the results of related studies of other fibrous materials, graphite fibers were shown to present little or no chronic health risk to people under present conditions of manufacture and use. Health effects appear to be limited to temporary skin irritations and upper respiratory tract irritations. Use of the fibers has grown in recent years, mostly because of the environmental health hazards associated with asbestos fibers.[7]

The environmental stability of several kinds of intercalated graphite fiber was investigated. The degree of environmental stability of this new conductive kind of graphite fiber will determine whether or not it can be used commercially. Four types of graphite fiber were tested; fibers intercalated with bromine, with iodine monochloride, with ferric chloride, and with cupric chloride. All four types were unstable under conditions where water was absorbed from the air, but stable under conditions of high vacuum, such as found in space. When all the other tests were considered, bromine intercalated fiber appeared to be most stable.[8]

Some experiments at Rice University with laser vaporization of graphite yielded a stable 60 carbon atom molecule, which was given the name "buckminsterfullerene." The name was chosen because of its hypothetical structure; it seems to most closely resemble a truncated icosahedron or two geodesic domes attached at the base—soccerball shaped. The technique used to synthesize this material was laser vaporization of solid graphite into a pulsed high-density helium flow. The same researchers also discovered similarly shaped molecules composed of carbon atoms with a lanthanum atom at the center. If the molecule is stable in the condensed phase, it probably would have some unique chemical properties. So far, the molecule appears to be rather inert. This serendipitous discovery was the result of research into the formation of lengthy carbon chains in interstellar space.[9]

Sumitomo Electric Co. perfected a technique for the mass production of large industrial diamonds from graphite. The graphite was subjected to ultrahigh pressure in the range of 50,000 to 60,000 atmospheres at a temperature of 1,400° C to 1,600° C for 100 hours. Until now, only small-sized diamonds have been mass produced. The firm plans to underprice natural diamond slightly for sales mainly to the semiconductor and precision toolmaking industries.[10]

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[1] Physical scientist, Division of Industrial Minerals.

[2] Metal Bulletin Monthly. Present Imperfect-Future Uncertain. Changes and Challenges at Great Lakes Carbon. No. 176, Aug. 1985, pp. 9-19.

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[3] U.S. Department of Commerce, International Trade Administration, Nonferrous Metals Division. A Competitive Assessment of Selected Reinforced Composite Fibers. Sept. 1985, 48 pp.

[4] Robbins, J. The Industrial Minerals of West Germany. Ind. Miner. (London), No. 219, Dec. 1985, pp. 41-42.

[5] Metal Bulletin Monthly. Electric Arcs Challenge to the Integrated. No. 174, June 1985, pp. 43-46.

[6] Tenney, D. R., and H. B. Dexter. Advances in Composites Technology. NASA Tech. Memo. 86353, Jan. 1985, 32 pp.

[7] Dahlquist, B. H. Evaluation of Health Aspects of Carbon Fibers. Air Force Inst. of Tech., Wright-Patterson AFB, OH, 1984, 60 pp.; NTIS AD-A151 563/4 WEP.

[8] Gaier, J. R., and D. A. Jaworske. Environmental Stability of Intercalated Graphite Fiber. Nat. Aeronaut. and Space Admin., Cleveland, OH, May 1985, 16 pp.; NTIS N85-26992/6/WMS.

[9] Baum, R. M. Laser Vaporization of Graphite Gives Stable 60-Carbon Molecules. Chem. and Eng. News, v. 63, No. 51, Dec. 23, 1985, pp. 20-22.

[10] Industrial Minerals (London). Synthetic Diamond Breakthrough. No. 213, June 1985, p. 10.

# Gypsum

## By Lawrence L. Davis[1]

The gypsum industry, spurred by lower interest rates and pent-up demand for housing, with 1.7 million public and private housing unit starts in 1985, ended the year with record-high shipments of gypsum wallboard, 19.5 billion square feet, an increase of 7%. Output of crude gypsum and calcined gypsum also increased. Sales of gypsum products increased slightly to 25 million short tons valued at $2.4 billion. Imports for consumption of crude gypsum increased 11% to about 10 million tons. Total value of gypsum product exports decreased 12% to $26 million.

**Domestic Data Coverage.**—Domestic production data for gypsum are developed by the Bureau of Mines from a survey of U.S. gypsum operations. Of the 130 operations to which the annual survey request was sent, all responded, representing 100% of the total production shown in tables 1 and 2.

**Table 1.—Salient gypsum statistics**

(Thousand short tons and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Active mines and plants[1] | 113 | 109 | 111 | 113 | 116 |
| Crude: | | | | | |
| Mined | 11,497 | 10,538 | 12,884 | 14,319 | 14,726 |
| Value | $98,101 | $89,131 | $101,361 | $113,671 | $114,229 |
| Imports for consumption | 7,593 | 6,718 | 8,031 | 8,904 | 9,922 |
| Byproduct gypsum sales | 696 | 697 | 760 | 780 | 779 |
| Calcined: | | | | | |
| Produced | 11,687 | 11,243 | 13,902 | 15,450 | 15,982 |
| Value | $243,140 | $196,488 | $270,136 | $320,518 | $366,581 |
| Products sold (value) | $1,196,236 | $1,121,775 | $1,605,605 | $2,274,261 | $2,418,296 |
| Exports (value) | $35,434 | $29,550 | $32,088 | $29,852 | $26,419 |
| Imports for consumption (value) | $51,720 | $53,646 | $87,880 | $169,667 | $155,422 |
| World: Production | $^{r}$83,970 | $^{r}$79,847 | 86,718 | $^{p}$86,767 | $^{e}$89,220 |

$^{e}$Estimated. $^{p}$Preliminary. $^{r}$Revised.

[1] Each mine, calcining plant, or combination mine and plant is counted as one establishment; includes plants that sold byproduct gypsum.

## DOMESTIC PRODUCTION

The United States remained the world's leading producer of gypsum, accounting for 17% of the total world output.

Crude gypsum was mined by 39 companies at 67 mines in 21 States. Production increased 3%. Leading producing States, in descending order, were Texas, Michigan, Iowa, Oklahoma, California, and Nevada. These six States produced more than 1 million tons each and together accounted for 65% of total domestic production. Stocks of crude ore at mines and plants at yearend were 3 million tons.

Leading companies were U.S.G. Corp., 12 mines; National Gypsum Co., 7 mines; Georgia-Pacific Corp., 6 mines; Celotex Corp., a subsidiary of Jim Walter Corp., and Genstar Gypsum Products Co., 3 mines each; and Weyerhaeuser Co., 1 mine. These 6 companies, operating 32 mines, produced

79% of the total crude gypsum.

Leading individual mines, in descending order of production, were U.S.G.'s Plaster City Mine, Imperial County, CA; U.S.G.'s Sweetwater Mine, Nolan County, TX; U.S.G.'s Alabaster Mine, Iosco County, MI; U.S.G.'s Shoals Mine, Martin County, IN; National Gypsum's Tawas Mine, Iosco County, MI; Weyerhaeuser's Briar Mine, Howard County, AR; U.S.G.'s Southard Mine, Blaine County, OK; National Gypsum's Sun City Mine, Barber County, KS; Georgia-Pacific's Acme Mine, Hardeman County, TX; and Republic Gypsum Co.'s Duke Mine, Jackson County, OK. These 10 mines accounted for 41% of the national total. Average output per mine for the 67 U.S. mines increased 6% to 219,800 tons.

Gypsum was calcined by 14 companies at 71 plants in 30 States, principally for the manufacture of gypsum wallboard and plaster. Calcined output increased 3% in tonnage and 14% in value. Leading States, in descending order, were Texas, California, Florida, Iowa, and New York. These 5 States, with 24 plants, accounted for 41% of the national output.

Leading companies were U.S.G., 22 plants; National Gypsum, 18 plants; Georgia-Pacific, 9 plants; Genstar, 5 plants; and Celotex, 4 plants. These 5 companies, operating 58 plants, accounted for 82% of the national output.

Leading individual plants were, in descending order of production, U.S.G.'s Jacksonville plant, Duval County, FL; U.S.G.'s Plaster City plant, Imperial County, CA; U.S.G.'s Sweetwater plant, Nolan County, TX; Weyerhaeuser's Briar plant, Howard County, AR; National Gypsum's Tampa plant, Hillsborough County, FL; U.S.G.'s Stony Point plant, Rockland County, NY; U.S.G.'s Shoals plant, Martin County, IN; National Gypsum's Medicine Lodge Plant, Barber County, KS; Georgia-Pacific's Acme plant, Hardeman County, TX; and Genstar's Las Vegas plant, Clark County, NV. These 10 plants accounted for 27% of the national production. Average calcine production for the 71 U.S. plants was 225,100 tons, a slight increase.

The following companies sold a total of 779,000 tons of byproduct gypsum, valued at $6 million, principally for agricultural use, but some for gypsum wallboard manufacturing: Allied Chemical Corp. and J. R. Simplot Co., both in California; Occidental Petroleum Corp. in Florida; Kemira Inc. in Georgia; SCM Pigments Div. of SCM Corp. in Maryland; and Texasgulf Inc. in North Carolina. Approximately 22% was of nonphosphogypsum origin, compared with 19% in 1984. Some byproduct gypsum was mixed with natural gypsum and commercially used in the manufacture of wallboard at U.S.G.'s Baltimore, MD, plant using byproduct gypsum obtained from SCM Pigments Div.'s plant in Baltimore.

Gypsum wallboard plant capacity increased 4% to 21.63 billion square feet. Total wallboard shipments were 19.5 billion square feet, indicating a 90% utilization of operating capacity. Shipments were a new record-high, a 7% increase compared with that of 1984.

One new gypsum mine was opened during the year. Eagle Gypsum Ltd.'s Eagle Mine in Eagle County, CO, produced gypsum for use as a cement set retarder.

Thomas Peck & Sons Inc. operated its mine near Nephi, UT, on an intermittent basis because of excessive fugitive dust emissions during the dry summer months and flooding problems in the wet months. The gypsum was used for cement production at portland cement plants in Juab and Salt Lake Counties.

At yearend, Piedmont Energy Inc. of Salt Lake City, UT, purchased Houston-based Standard Gypsum Corp., a gypsum importer with facilities at Tampa, FL.[2]

A new company, Atlantic Gypsum Co. Inc., was planning a $34 million gypsum importing, processing, and wallboard manufacturing facility at Port Newark, NJ. The plant, to be fed by at least 250,000 tons per year of imported gypsum, was expected to begin operation in the spring of 1987.[3]

Winn Rock Inc.'s Winnfield Mine in Winn Parish, LA, the only anhydrite mine in the United States, produced rock mainly for road construction, but some was sold for use as a cement set retarder.

Reflecting sporadic markets for crude gypsum sold for cement or agricultural use, several gypsum mines remained closed during the year. CalMat Co.'s Shoveler Annex Mine in Imperial County, CA, was idle. Ernest W. Munroe, Joe C. Lackey, Colorado Lien Co., all in Colorado, were dormant. E. J. Wilson & Sons' Lidy Hot Springs Mine in Lemhi County, ID, remained inactive but shipped some gypsum from stockpile for agricultural use. Walter Fisk's Lovelock Mine in Pershing County, NV, was inactive. Raymond Schweitzer Gypsum Co.'s Calumet Mine in Canadian County, OK, and Walton Gypsum Co.'s Okeene Mine in Blaine County, OK, remained dormant.

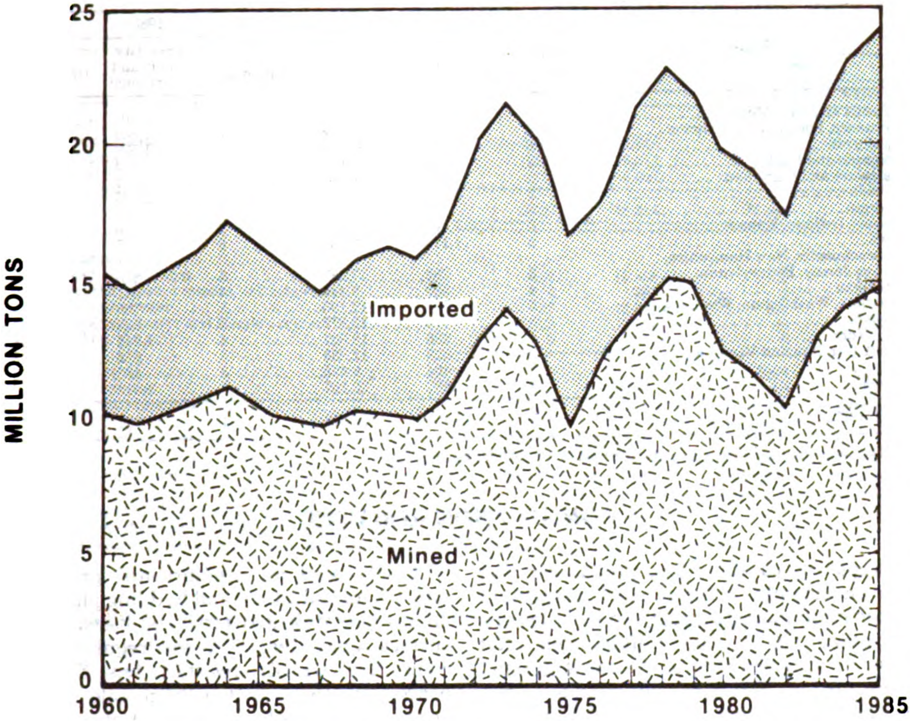

**Figure 1.—Supply of crude gypsum in the United States.**

**Table 2.—Crude gypsum mined in the United States, by State**

| State | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Active mines | Quantity (thousand short tons) | Value (thousands) | Active mines | Quantity (thousand short tons) | Value (thousands) |
| Arizona | 4 | 261 | $2,332 | 4 | 251 | $1,926 |
| Arkansas, Kansas, Louisiana | 5 | 1,465 | 9,577 | 5 | 1,365 | 7,740 |
| California | 10 | 1,382 | 12,443 | 8 | 1,332 | 12,201 |
| Colorado, Idaho,[1] Montana, South Dakota, Washington | 7 | 428 | 3,576 | 7 | 375 | 3,086 |
| Indiana, New York, Ohio, Virginia | 5 | 1,844 | 14,330 | 5 | 1,870 | 14,832 |
| Iowa | 6 | 1,527 | 12,421 | 6 | 1,639 | 13,682 |
| Michigan | 5 | 1,534 | 10,304 | 5 | 1,772 | 11,883 |
| Nevada | 4 | 1,192 | 8,860 | 4 | 1,207 | 8,942 |
| New Mexico | 3 | 318 | 1,622 | 3 | 350 | 1,570 |
| Oklahoma | 6 | 1,549 | 13,485 | 6 | 1,595 | 12,548 |
| Texas | 7 | 2,166 | 19,431 | 7 | 1,981 | 17,299 |
| Utah | 4 | 277 | 2,671 | 4 | 413 | 4,033 |
| Wyoming | 3 | 376 | 2,618 | 3 | 576 | 4,488 |
| Total[2] | 69 | 14,319 | 113,671 | 67 | 14,726 | 114,229 |

[1] 1984 only.

[2] Data may not add to totals shown because of independent rounding.

**Table 3.—Calcined gypsum produced in the United States, by State**

| State | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Active plants | Quantity (thousand short tons) | Value (thousands) | Active plants | Quantity (thousand short tons) | Value (thousands) |
| Arizona and New Mexico | 3 | 382 | $8,770 | 3 | 404 | $10,016 |
| Arkansas, Louisiana, Oklahoma | 6 | 1,600 | 30,318 | 6 | 1,664 | 34,905 |
| California | 6 | 1,519 | 35,364 | 6 | 1,606 | 41,325 |
| Colorado and Utah | 3 | 352 | 7,010 | 3 | 354 | 8,164 |
| Delaware and Maryland | 3 | 783 | 16,695 | 3 | 732 | 17,165 |
| Florida | 3 | 1,160 | 25,774 | 3 | 1,185 | 27,974 |
| Georgia | 3 | 702 | 15,940 | 3 | 740 | 18,161 |
| Illinois, Indiana, Kansas | 6 | 1,405 | 25,765 | 6 | 1,445 | 28,862 |
| Iowa | 5 | 1,173 | 22,931 | 5 | 1,168 | 26,589 |
| Massachusetts, New Hampshire, New Jersey, Pennsylvania | 5 | 789 | 17,387 | 5 | 820 | 20,084 |
| Michigan | 4 | 500 | 9,446 | 4 | 571 | 12,217 |
| Montana, Washington, Wyoming | 5 | 701 | 17,195 | 5 | 705 | 19,951 |
| Nevada | 3 | 779 | 13,877 | 3 | 825 | 16,674 |
| New York | 4 | 986 | 19,627 | 4 | 1,046 | 24,408 |
| North Carolina and Virginia | 3 | 628 | 12,835 | 3 | 672 | 15,676 |
| Ohio | 3 | 404 | 9,425 | 3 | 432 | 9,998 |
| Texas | 6 | 1,587 | 32,157 | 6 | 1,614 | 34,412 |
| Total[1] | 71 | 15,450 | 320,518 | 71 | 15,982 | 366,581 |

[1] Data may not add to totals shown because of independent rounding.

## CONSUMPTION AND USES

Apparent consumption, production plus net imports plus industry stock changes, of crude gypsum, including byproduct gypsum, increased 5% to 25.4 million tons. Net imports provided 33% of the crude gypsum consumed. Apparent consumption of calcined gypsum increased 4% to 15.9 million tons.

Yearend stocks of crude gypsum at mines and calcining plants were 3 million tons. Of this, 46% was at calcining plants in coastal States.

Of the total gypsum products sold or used, 5.6 million tons, 23%, was uncalcined. Of the total uncalcined gypsum, 76% was used for portland cement, and 21% was used in agriculture. Of the total calcined gypsum, 96% was used for prefabricated products and 4% for industrial and building plasters. Of the prefabricated products, based upon surface square feet, 67% was regular wallboard; 22% was fire-resistant type X wallboard; 3% was 5/16-inch mobile home board; 5% was lath, veneer base, sheathing, and predecorated wallboard; and 3% was miscellaneous board including water- and/or moisture-resistant board. Of the regular wallboard, 83% was 1/2-inch and 11% was 5/8-inch. In descending order, the leading sales regions for prefabricated products were the South Atlantic, Pacific, and West South-Central, which accounted for 54% of the total.

### Table 4.—Gypsum products (made from domestic, imported, and byproduct gypsum) sold or used in the United States, by use

(Thousand short tons and thousand dollars)

| Use | 1984 Quantity | 1984 Value | 1985 Quantity | 1985 Value |
|---|---|---|---|---|
| Uncalcined: | | | | |
| Portland cement | 4,286 | 41,046 | 4,256 | 38,623 |
| Agriculture[1] | 1,326 | 18,671 | 1,180 | 16,377 |
| Fillers and miscellaneous | 125 | 6,597 | 132 | 6,448 |
| Total | 5,737 | 66,314 | [2]5,567 | 61,448 |
| Calcined: | | | | |
| Building plaster: | | | | |
| Regular base coat | 155 | 15,356 | 149 | 15,027 |
| Poured gypsum cement and concrete | 4 | 365 | 2 | 192 |
| Veneer plaster | 89 | 12,680 | 102 | 15,190 |
| Gauging plaster and Keene's cement | 23 | 3,030 | 26 | 3,561 |
| Other | 9 | 1,201 | 8 | 1,105 |
| Total | 280 | [2]32,633 | [2]288 | 35,075 |
| Industrial plaster | 453 | 45,866 | 510 | 55,426 |
| Prefabricated products[3] | 17,572 | 2,129,448 | 18,320 | 2,266,348 |
| Total calcined | 18,305 | 2,207,947 | [2]19,117 | 2,356,849 |
| Grand total | 24,042 | 2,274,261 | [2]24,684 | [2]2,418,296 |

[1] Includes most of 779,603 tons of byproduct gypsum in 1984 and most of 778,515 tons in 1985.
[2] Data do not add to total shown because of independent rounding.
[3] Includes weight of paper, metal, or other materials, and some byproduct gypsum.

### Table 5.—Prefabricated gypsum products sold or used in the United States

| Product | 1984 Thousand square feet | 1984 Thousand short tons[1] | 1984 Value (thousands) | 1985 Thousand square feet | 1985 Thousand short tons[1] | 1985 Value (thousands) |
|---|---|---|---|---|---|---|
| Lath: | | | | | | |
| 3/8 inch | 30,600 | 23 | $4,282 | 27,800 | 21 | $4,404 |
| 1/2 inch | 1,500 | 1 | 202 | 1,750 | 2 | 237 |
| Total[2] | 32,100 | 24 | 4,484 | 29,550 | 22 | 4,641 |
| Veneer base | 408,270 | 470 | 50,882 | 428,860 | 435 | 58,167 |
| Sheathing | 337,720 | 325 | 49,773 | 349,860 | 328 | 52,389 |
| Regular gypsumboard: | | | | | | |
| 3/8 inch | 475,283 | 361 | 54,047 | 454,246 | 340 | 53,301 |
| 1/2 inch | 10,490,118 | 9,262 | 1,135,688 | 10,851,776 | 9,539 | 1,134,940 |
| 5/8 inch | 1,298,586 | 1,430 | 162,942 | 1,395,919 | 1,252 | 173,496 |
| 1 inch | 61,600 | 126 | 13,513 | 79,900 | 142 | 18,532 |
| Other[3] | 162,370 | 125 | 18,880 | 276,220 | 180 | 31,898 |
| Total[2] | 12,487,957 | 11,304 | 1,385,069 | 13,058,061 | 11,453 | 1,412,168 |
| Type X gypsumboard | 4,040,744 | 4,677 | 507,100 | 4,387,049 | 5,015 | 546,862 |
| Predecorated wallboard | 127,110 | 134 | 41,013 | 134,650 | 129 | 45,346 |
| 5/16-inch mobile home board | 853,850 | 615 | 87,704 | 651,549 | 489 | 64,567 |
| Other[4] | 25,930 | 23 | 3,423 | 483,420 | 448 | 82,209 |
| Grand total[2] | 18,313,681 | 17,572 | 2,129,448 | 19,522,999 | 18,320 | 2,266,348 |

[1] Includes weight of paper, metal, or other material.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes 1/4-, 7/16-, and 3/4-inch gypsumboard.
[4] Includes approximately 478,000 square feet of water- and/or moisture-resistant board in 1985.

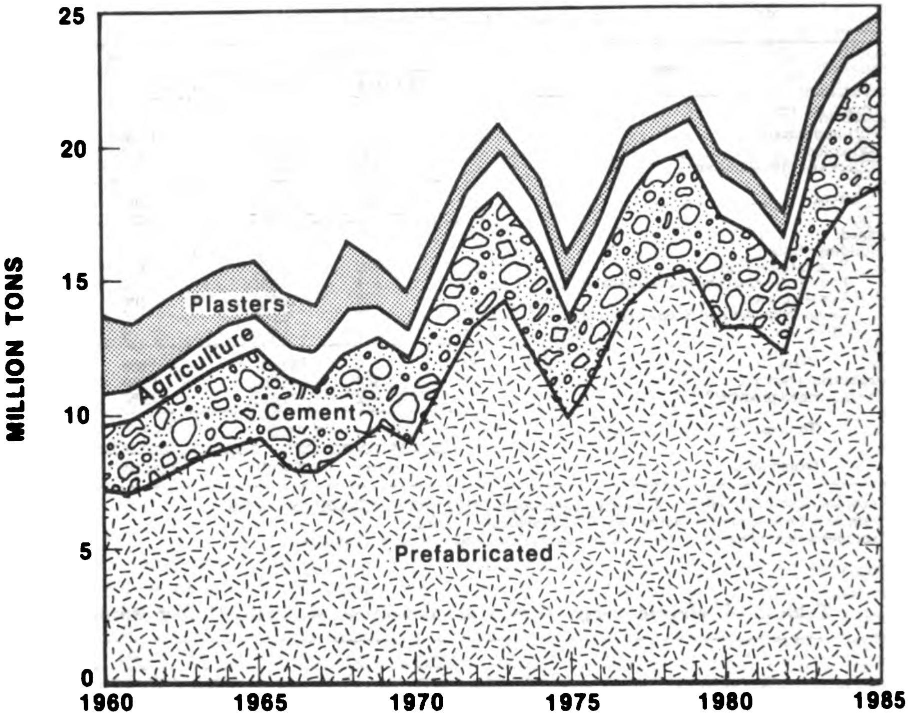

Figure 2.—Sales of gypsum products, by use.

## ENERGY

Efficient production scheduling, superior insulation, and energy-saving processing equipment such as one-step drying and calcining continued to improve the utilization of energy per unit of wallboard as in the past few years. Energy consumption per thousand square feet of gypsum wallboard sales decreased slightly to 2.42 million British thermal units.

As reported by the Gypsum Association, fuel sources for the gypsum industry were natural gas, 84.5%; electricity, 6.5%; propane, 1.0%; No. 2 fuel oil, 2.8%; No. 4 and No. 6 fuel oil, 2.0%; and coal, 3.0%.

## PRICES

On an average value per ton basis, crude gypsum decreased slightly to $7.76, calcined gypsum increased 13% to $23.53, and byproduct gypsum decreased 7% to $7.70.

The average value of gypsum products sold or used increased 4% to $97.97 per ton. Prefabricated products were valued at $123.71 per ton, industrial plasters at $108.68 per ton, building plaster at $121.79 per ton, and uncalcined products at $11.04 per ton.

Quoted prices for gypsum products were published monthly in Engineering News-Record. Prices in December, based on truck lots delivered to the job, showed a wide range. Regular 1/2-inch wallboard prices ranged from $97 per thousand square feet at Dallas and Denver to $268 at Boston. Average price in December for 20 cities was $173 per thousand square feet, with some minor discounts for prompt payment. This represented a slight increase compared with that of December 1984.

## FOREIGN TRADE

The gypsum industry continued to rely on imports of crude gypsum rock for a significant fraction, 33%, of apparent consumption. Imports of crude gypsum, principally from Canada, 66%; Mexico, 22%; and Spain, 12%, increased 11% to 9.9 million tons. Spanish imports into the South Atlantic Coast and Gulf Coast States increased 31% to 1.2 million tons. Most of the imported crude gypsum was mined by subsidiaries of U.S. companies in Canada and Mexico.

Total value of gypsum and gypsum products imported was $155 million, a decrease of 8%. Gypsum wallboard imports, principally from Canada, 82%, were 786 million square feet, a 9% decrease. Total value of gypsum product exports to all countries was $26 million, a 12% decrease.

### Table 6.—U.S. exports of gypsum and gypsum products

(Thousand short tons and thousand dollars)

| Year | Crude, crushed, or calcined | | Other manufactures, n.e.c. (value)[1] | Total value |
|---|---|---|---|---|
| | Quantity | Value | | |
| 1983 | 117 | 13,621 | 18,467 | 32,088 |
| 1984 | 131 | 12,711 | 17,141 | 29,852 |
| 1985 | 83 | 13,021 | 13,398 | 26,419 |

[1] Includes gypsum or plaster building boards and lath (TSUS 245.7000) and articles, n.s.p.f., of plaster of paris (TSUS 512.4500).

Source: Bureau of the Census.

### Table 7.—U.S. imports for consumption of gypsum and gypsum products

(Thousand short tons and thousand dollars)

| Year | Crude | | Ground or calcined | | Alabaster manufactures[1] (value) | Plaster-board[2] (value) | Other manufactures, n.s.p.f.[3] (value) | Total value |
|---|---|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | | | | |
| 1983 | 8,031 | 56,960 | 4 | 305 | 1,922 | 26,200 | 2,492 | [4]87,880 |
| 1984 | 8,904 | 73,965 | 11 | 392 | 3,300 | 86,962 | 5,048 | 169,667 |
| 1985 | 9,922 | 64,089 | 2 | 242 | 5,173 | 80,119 | 5,799 | 155,422 |

[1] Includes imports of jet manufactures, which are believed to be negligible.
[2] Includes gypsum or plaster building boards and lath (TSUS 245.7000).
[3] Comprised of statues and articles, n.s.p.f., of plaster of paris (TSUS 512.4100 and 512.4400) and gypsum cement, (TSUS 512.3100 and 512.3500).
[4] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

### Table 8.—U.S. imports for consumption of crude gypsum, by country

(Thousand short tons and thousand dollars)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Australia | 15 | 160 | 16 | 130 |
| Canada[1] | 6,006 | 58,980 | 6,516 | 45,445 |
| Jamaica | 112 | 977 | 17 | 118 |
| Mexico | 1,837 | 7,392 | 2,162 | 9,896 |
| Spain | 922 | 6,312 | 1,207 | 8,052 |
| Other | 12 | 143 | 4 | 447 |
| Total[2] | 8,904 | 73,965 | 9,922 | 64,089 |

[1] Includes anhydrite.
[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

Production of gypsum from small deposits in the developing countries has been intermittent and often unreported. Total world production figures might be somewhat low because, in many countries, significant mine production was consumed captively in integrated industrial plants producing wallboard, plaster, and plaster products, and was unreported.

**Canada.**—Canada was the second largest producer of crude gypsum, accounting for 10% of the world total. Shipments increased 9% to 9.3 million tons, 75% of which came from Nova Scotia.

Canada exported 6.4 million tons of crude gypsum, almost 70% of its production. Over 99% of the exports were to the United States, principally to wallboard plants in the Atlantic and Gulf Coast States. Canada imported about 120,000 tons of crude gypsum, over 70% of which came from Mexico.

Production of wallboard products decreased because of a 4-month strike at Domtar Inc.'s plant at Caledonia, Ontario. As a result, exports to the United States decreased from the record high set in 1984. Wallboard imports increased greatly in 1985 because of reduced production and an increase in Canadian demand.

Domtar purchased the gypsum wallboard plants of Genstar Gypsum Ltd. at Edmonton, Alberta, and Saskatoon, Saskatchewan. Westroc Industries Ltd. announced that its Vancouver, British Columbia, plant would be closed. Westroc then purchased Genstar Gypsum's gypsum wallboard plant in Vancouver.[4]

The Gypsum Association in the United States, of which all Canadian gypsum wallboard manufacturers were members, announced that yearend Canadian wallboard capacity was 3.64 billion square feet, a slight decrease from that of 1984.

**Finland.**—Kemira Oy opened a plant to produce paper coating pigments using phosphogypsum. The plant, at Siilinjarvi, has a capacity of 55,000 tons per year.[5]

**Germany, Federal Republic of.**—The Federal Republic of Germany is one of Western Europe's major producers of crude gypsum and a world leader in specialty gypsum used in molding, dental, and pharmaceutical applications that require very high purity gypsum. The largest producer of crude gypsum is Gebr. Knauf Westdeutsche Gipswerke with a capacity of about 3.3 million tons per year from 11 mines in Bavaria and 6 others in Baden-Württemberg, Hessen, Saarland, and Lower Saxony. The second largest crude gypsum producer is Rigips Baustoffwerke GmbH, with numerous mines in Baden-Württemberg and two in Lower Saxony. Both companies produce building plaster and wallboard. Another 20 or so smaller companies produce gypsum retarders for the cement industry, building plasters, high-purity specialty plasters, and gypsum blocks.[6]

**Libya.**—Libya awarded a contract to develop a 220,000- to 330,000-ton-per-year gypsum mine and to construct export facilities at a port east of Tripoli. Most of the crude gypsum was expected to be exported to Scandinavia and Europe and the remainder used to supply domestic demand for plaster and wallboard products.[7]

**Thailand.**—Fueled by rapid growth in building construction in the Bangkok area, gypsum production, used mainly by the cement industry, increased about 13%. Exports, mainly to Taiwan and Malaysia, increased slightly. Exports faced increased competition from Australia and India.[8] Major gypsum deposits are in the northern Provinces of Pichit and Nakhon Sawan and the southern Provinces of Nakhon Si Thammarat and Surat Thani. The largest producers in the north are Thai Gypsum Co. Ltd. and its affiliate Thai Gypsum Products Co. Ltd. with a combined capacity of 330,000 tons per year of crude gypsum. In the southern Province of Surat Thani, Taksin Sahakarn Co. Ltd. is the largest producer, while in Nakhon Si Thammarat Chokpana Co. Ltd. and S. K. Minerals are the principal producers.[9]

## Table 9.—Gypsum: World production, by country[1]

(Thousand short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Afghanistan | [r] [e]3 | [2]3 | [r] [e]3 | [r] [e]3 | 3 |
| Algeria[e] | 220 | 220 | 275 | 275 | 275 |
| Angola[e] | 22 | 22 | 22 | [r]22 | 22 |
| Argentina | 739 | 679 | 637 | 625 | 585 |
| Australia | 1,932 | 2,054 | 1,664 | 678 | 1,100 |
| Austria[3] | 882 | 802 | 828 | 816 | 830 |
| Belgium[3] | 170 | -- | -- | -- | -- |
| Bolivia | 1 | 1 | [e]1 | [e]1 | 1 |
| Brazil | 659 | 750 | 613 | 544 | 610 |
| Bulgaria | 386 | 414 | 425 | 433 | 435 |
| Burma[4] | 34 | 29 | 38 | 43 | [2]43 |
| Canada (shipments)[3] | 7,744 | 6,600 | 8,275 | 8,550 | 9,300 |
| Chile | [r]262 | [r]99 | 73 | 185 | [2]216 |
| China[e] | 3,700 | 3,900 | 4,700 | 5,300 | 5,500 |
| Colombia | [r]328 | 309 | 247 | 287 | 300 |
| Cuba[e] | 143 | 140 | 145 | 145 | 145 |
| Cyprus | [r]44 | [r]33 | 35 | 24 | 25 |
| Czechoslovakia | 845 | 875 | 935 | 928 | 840 |
| Dominican Republic | [2]225 | [e]230 | [e]230 | [e]230 | 255 |
| Ecuador | [2]2 | [e]2 | [e]2 | [e]2 | 2 |
| Egypt | 1,047 | 1,026 | 795 | [e]800 | 800 |
| El Salvador[e] | 7 | 6 | 5 | 5 | 4 |
| Ethiopia | 5 | 4 | [e]5 | [e]5 | 5 |
| France[3] | 6,839 | 6,657 | 6,111 | 5,954 | 6,000 |
| German Democratic Republic[e] | [r]397 | [r]397 | [r]397 | [r]397 | 397 |
| Germany, Federal Republic of (marketable)[3] | 2,122 | 1,897 | 2,739 | [e]2,400 | 2,200 |
| Greece | 694 | 756 | [r] [e]760 | [r] [e]760 | 750 |
| Guatemala | 32 | 31 | 43 | 28 | 27 |
| Honduras[e] | 22 | 22 | [r]25 | 25 | 25 |
| India | 1,045 | 1,070 | 1,145 | 1,519 | [2]1,239 |
| Iran | [2]6,600 | [e]5,500 | [e]6,000 | [e]5,500 | 5,500 |
| Iraq[e] | 190 | 190 | 190 | 330 | 330 |
| Ireland | [r]396 | 409 | 388 | 358 | 360 |
| Israel | 46 | 46 | 46 | 46 | 46 |
| Italy | 1,702 | 1,472 | 1,530 | 1,393 | 1,400 |
| Jamaica | 206 | 118 | 119 | [e]200 | 220 |
| Japan[5] | 6,765 | 7,014 | 6,443 | [e]6,700 | 6,900 |
| Jordan | 58 | 44 | 45 | 121 | 120 |
| Kenya[3] | -- | ([6]) | 1 | [r] [e]2 | 2 |
| Korea, Republic of[5] | [e]700 | [e]800 | [e]1,000 | [2]558 | [2]873 |
| Laos | 45 | [e]70 | [e]80 | 90 | 120 |
| Lebanon | 10 | 6 | 6 | [e]6 | 3 |
| Libya | 198 | 193 | 198 | 198 | 198 |
| Luxembourg | 1 | ([6]) | [e] ([6]) | [e] ([6]) | ([6]) |
| Mauritania[e] | [2]2 | 6 | 4 | 1 | 1 |
| Mexico | 2,635 | 2,251 | 3,261 | 2,347 | 3,100 |
| Mongolia[e] | 35 | 35 | 35 | 35 | 35 |
| Morocco | 439 | 463 | 485 | [e]500 | 500 |
| Nicaragua | [e]33 | 22 | 13 | [e]10 | [2]9 |
| Niger[e] | 3 | 3 | 3 | 3 | 3 |
| Pakistan | [r]349 | [r]365 | 351 | 413 | 475 |
| Paraguay | 11 | 7 | 4 | 7 | 6 |
| Peru | [2]386 | [e]400 | [e]400 | [e]400 | 400 |
| Philippines[5] | 122 | 121 | 122 | 124 | 124 |
| Poland[3] | [2]1,445 | [e]1,430 | [e]1,430 | [e]1,430 | 1,490 |
| Portugal | 268 | 262 | 275 | [r] [e]265 | 275 |
| Romania[e] | 1,800 | 1,800 | 1,800 | 2,000 | 1,700 |
| Saudi Arabia | 386 | 400 | [e]550 | 331 | 330 |
| Sierra Leone | -- | -- | 4 | 4 | 4 |
| South Africa, Republic of | 612 | 590 | 571 | 590 | [2]505 |
| Spain | 5,829 | 5,564 | 6,195 | 5,914 | 5,800 |
| Sudan[3] | [r] [e]9 | [r] [e]9 | [e]9 | [2]9 | [2]7 |
| Switzerland[e] | 95 | [r]85 | 85 | 85 | 90 |
| Syria | 88 | [e]90 | 186 | 220 | 220 |
| Taiwan[5] | 7 | 2 | 3 | 2 | 2 |
| Tanzania[e] | 13 | 13 | 13 | 13 | 13 |
| Thailand | 596 | 831 | 838 | 1,224 | 1,380 |
| Tunisia[e] | 80 | 80 | [r]88 | [r]95 | 100 |
| Turkey | 100 | [e]100 | 83 | 64 | 66 |
| U.S.S.R.[e] [5] | 5,400 | 5,400 | 5,400 | 5,400 | 5,400 |
| United Kingdom[3] | 3,245 | 3,021 | 3,271 | 3,459 | [2]3,389 |
| United States[7] | 11,497 | 10,538 | 12,884 | 14,319 | [2]14,726 |
| Uruguay | ([6]) | 135 | 167 | 82 | 110 |
| Venezuela | 241 | 175 | 226 | 158 | [2]147 |

See footnotes at end of table.

Table 9.—Gypsum: World production, by country[1] —Continued

(Thousand short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Vietnam[e] | 17 | 30 | 30 | 30 | 30 |
| Yemen Arab Republic | [e]22 | 24 | 26 | 27 | 27 |
| Yugoslavia | 737 | 705 | 687 | [r] [e]720 | 750 |
| Total | [r]83,970 | [r]79,847 | 86,718 | 86,767 | 89,220 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through July 8, 1986.

[2] Reported figure.

[3] Includes anhydrite.

[4] Data are for years beginning Apr. 1 of that stated.

[5] Includes byproduct gypsum. (In the case of Japan, byproduct gypsum was virtually all the gypsum consumed during 1981-85.)

[6] Less than 1/2 unit.

[7] Excludes byproduct gypsum.

[8] Revised to zero.

## TECHNOLOGY

Windsor Gypsum Co. began construction of a gypsum wallboard plant near Tatum, TX, close to the Martin Lake powerplants of Texas Utilities Co. The raw material feed for the wallboard plant will be high-quality synthetic gypsum from the flue gas desulfurization system of the powerplants. This would be the first U.S. wallboard plant designed and constructed solely on the basis of a synthetic gypsum feed.

The Bureau of Mines conducted pull and creep tests on roof bolts anchored with gypsum plaster. Results showed that 2-foot bolts anchored with the gypsum plaster, which was allowed to cure for 10 minutes, sustained pull test loads equal to the ultimate strength of the bolt steel, about 37,000 pounds.[10]

The Bureau of Mines investigated possible high-volume uses of waste phosphogypsum. Admixtures of phosphogypsum, fly ash, and lime that could produce a coarse aggregate suitable for road construction were studied. Use of cement, cement-kiln dust, clays, oxychlorides, phosphogypsum asphalt, and silica were also investigated. It was found that a mix containing 7% grade AC-20 asphalt and 93% aggregate composed of 20% dried phosphogypsum, 30% sand, and 50% limestone met Florida Department of Transportation specifications for a type III surface course mix, a sand-asphalt hot mix for patching, and an ABC-1 base course mix. Thus, phosphogypsum could be used in asphalt-concrete mixes for surface or base courses or for patching, but none of the various mixes could meet specifications for wearing or friction courses.[11]

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[1] Physical scientist, Division of Industrial Minerals.

[2] Rock Products. V. 89, No. 1, Jan. 1986, p. 36.

[3] Page 8 of work cited in footnote 2.

[4] Stonehouse, D. H. Gypsum and Anhydrite. Can. Miner. Yearbook 1985, pp. 30.1-30.8.

[5] Griffiths, J. Kemira Mica-Utilising Resources. Ind. Miner. (London), No. 219, Dec. 1985, p. 81.

[6] Robbins, J. The Industrial Minerals of West Germany. Ind. Miner. (London), No. 219, Dec. 1985, pp. 23-24.

[7] Industrial Minerals (London). No. 219, Dec. 1985, p. 12.

[8] U.S. Embassy, Bangkok, Thailand. State Dep. Telegram 24749, May 28, 1986, sec. 17 and 18.

[9] Rachdawong, S. Industrial Minerals of Thailand. Ind. Miner. (London), No. 221, Feb. 1986, pp. 40-41.

[10] Hansen, J. S., and S. J. Gerdemann. Pull and Creep Tests on Gypsum-Bonded Roof Bolts. BuMines RI 8937, 1985, 36 pp.

[11] May, A., J. R. Cobble, and J. W. Sweeney. Assessment of Phosphogypsum as a Constituent of Aggregate Material. BuMines RI 8939, 1985, 21 pp.

# Helium

## By William D. Leachman[1]

Grade-A helium (99.995% or better) sales volume in the United States by private industry and the Bureau of Mines was 1,444 million cubic feet (MMcf) in 1985.[2] Grade-A helium exports by private producers were 439 MMcf, for total sales of 1,883 MMcf of U.S. helium. The Bureau's price, f.o.b. plant, for Grade-A helium was $37.50 per thousand cubic feet (Mcf). The price of Grade-A helium gas sold by private producers was about $36 per Mcf at the end of the year, and the price of liquid helium averaged $55 per Mcf gaseous equivalent with some producers posting surcharges to these prices.

**Domestic Data Coverage.**—Domestic production data for helium are developed by the Bureau of Mines from records of its own operations as well as the "High-Purity Helium" survey, a single, voluntary canvass of private U.S. operations. Of the six operations to which a survey request was sent, 100% responded, and those data plus data from the Bureau's operations represent 100% of the total production shown in table 2.

**Legislation and Government Programs.**—The Government's program for storage of private crude helium in the Government's helium storage facilities at the Cliffside Field near Amarillo, TX, was critical in supplying helium for the private helium market. Private helium production in 1985 was not sufficient to provide for the private market because one of its crude helium separation plants suspended operations in April. Private crude helium previously stored under contract with the Government was returned to the owners for purification as needed to provide for private industry's demand.

## DOMESTIC PRODUCTION

In 1985, 11 privately owned domestic helium plants were operated by 8 companies. Seven privately owned plants and one Bureau of Mines plant extracted helium from natural gas. Both private and Bureau plants use cryogenic extraction processes. Pressure-swing adsorption is used for helium purification at two newer private helium plants and at the Bureau's plant. Cryogenic purification is used by other producers. The Bureau and all six private plants that produce Grade-A helium also liquefy helium. They are Air Products and Chemicals Inc., Hansford County, TX; Navajo Refined Helium Co., Shiprock, NM; Kansas Refined Helium Co., Otis, KS; and Union Carbide Corp., Linde Div., in Bushton, Elkhart, and Ulysses, KS.

The volume of helium recovered from natural gas decreased in 1985 because one of the larger private crude helium plants shut down in April and did not resume operation owing to the declining market for natural gas and natural gas liquids. All of the natural gas processed for helium extraction came from the gasfields in Kansas, New Mexico, Oklahoma, and Texas.

The Bureau of Mines' 500-liter-per-hour helium liquefier was modified in 1985 to increase its efficiency. The control system was changed, and a wet-expansion engine was installed to increase its output. The modifications and new equipment increased liquefaction capacity about 30%, with an increase of only 11% in operating costs. The Federal demand for liquid helium continues to grow as national defense, space, and energy research and development projects using liquid helium increase.

## Table 1.—Ownership and location of helium extraction plants in the United States in 1985

| Category and owner or operator | Location | Product purity |
|---|---|---|
| Government-owned: | | |
| Bureau of Mines | Masterson, TX | Crude and Grade-A helium.[1] |
| Do | Keyes, OK | Helium tank car maintenance only.[2] |
| Private industry: | | |
| Air Products and Chemicals Inc | Hansford County, TX | Grade-A helium.[1] |
| Cities Service Cryogenics Inc | Scott City, KS | Crude helium.[3] |
| Cities Service Helex Inc | Ulysses, KS | Crude helium. |
| Kansas Refined Helium Co | Otis, KS | Grade-A helium.[1] |
| Navajo Refined Helium Co | Shiprock, NM | Do. |
| Northern Helex Co | Bushton, KS | Crude helium. |
| Phillips Petroleum Co | Dumas, TX | Do. |
| Do | Hansford County, TX | Do. |
| Union Carbide Corp., Linde Div | Bushton, KS | Grade-A helium.[1] |
| Do | Elkhart, KS | Do. |
| Do | Ulysses, KS | Do. |

[1] Including liquefaction.
[2] Tank car maintenance relocated to Masterson, TX, in May 1985. Keyes plant deactivated.
[3] Output is piped to Ulysses, KS, for purification.

## Table 2.—Helium recovery in the United States[1]

(Thousand cubic feet)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Crude helium: | | | | | |
| Bureau of Mines: | | | | | |
| Total storage | -257,799 | -350,235 | -275,714 | -314,969 | -411,681 |
| Private industry: | | | | | |
| Stored by Bureau of Mines | 452,880 | 113,261 | 282,018 | 506,092 | 487,576 |
| Withdrawn | -304,987 | -724,113 | -729,134 | -605,935 | -956,462 |
| Total private industry storage | 147,893 | -610,852 | -447,116 | -99,843 | -468,886 |
| Total crude helium | -109,906 | -961,087 | -722,830 | -414,812 | -880,567 |
| Stored private crude helium withdrawn from storage and purified by the Bureau of Mines for redelivery to industry | -80,208 | -51,234 | -65,015 | -49,057 | -5,339 |
| Grade-A helium: | | | | | |
| Bureau of Mines sold | 240,880 | 305,071 | 241,733 | 294,460 | 397,446 |
| Private industry sold | 1,014,543 | 939,496 | 1,120,955 | 1,342,961 | 1,485,662 |
| Total sold | 1,255,423 | 1,244,567 | 1,362,688 | 1,637,421 | 1,883,108 |
| Total stored | -190,114 | -1,012,321 | -787,845 | -463,869 | -885,906 |
| Grand total recovery | 1,065,309 | 232,246 | 574,843 | 1,173,552 | 997,202 |

[1] Negative numbers denote net withdrawal from the Government's underground helium storage facility, a partially depleted natural gas reservoir in Cliffside Field near Amarillo, TX.

## Table 3.—Summary of Bureau of Mines helium plant operations

(Thousand cubic feet)

| | 1983 | 1984 | 1985 |
|---|---|---|---|
| Grade-A supply: | | | |
| Inventory at beginning of period[1] | 20,368 | 22,400 | 18,163 |
| Helium recovered: Exell plant[2]: | 308,780 | 339,280 | 387,795 |
| Total | 329,148 | 361,680 | 405,958 |
| Grade-A disposal: | | | |
| Sales | 241,733 | 294,460 | 397,446 |
| Redelivered to private producers | 65,015 | 49,057 | 5,339 |
| Inventory at end of period[1] | 22,400 | 18,163 | 3,173 |
| Total | 329,148 | 361,680 | 405,958 |

[1] At Amarillo and Exell helium plants.
[2] Includes 65,015 Mcf purified for private industry in 1983, 49,057 Mcf in 1984, and 5,339 in 1985.

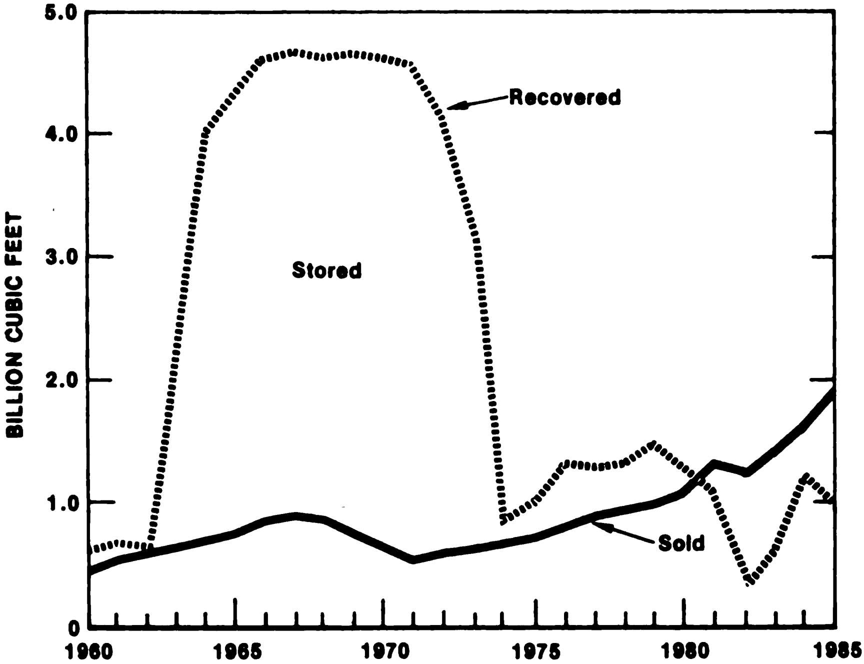

Figure 1.—Helium recovery in the United States, 1960-85.

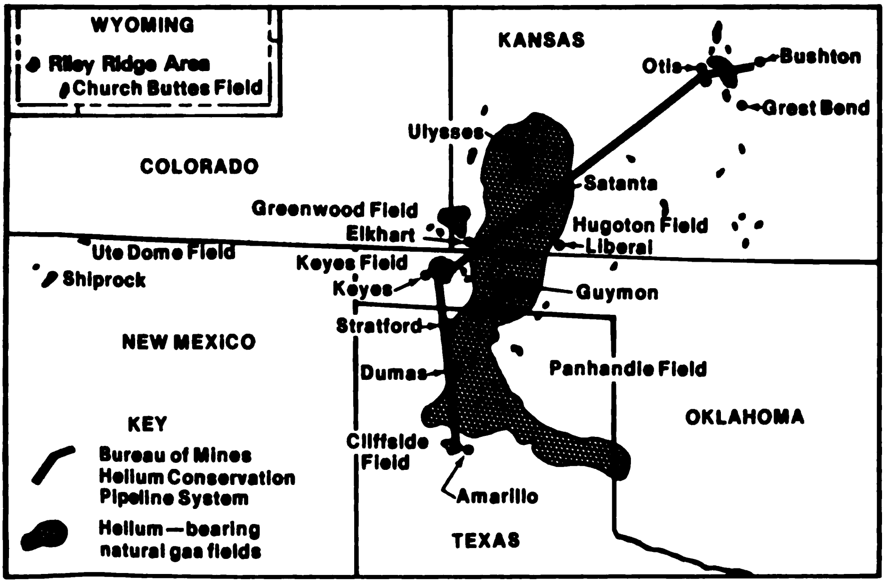

Figure 2.—Major U.S. helium-bearing natural gas fields.

## CONSUMPTION AND USES

The major domestic end uses of helium were cryogenics, welding, and pressurizing and purging. Minor uses included synthetic breathing mixtures, chromatography, leak detection, lifting gas, heat transfer, and controlled atmospheres. The Pacific and Gulf Coast States were the principal areas for helium demand.

Nine more successful space shuttle launches were made by the National Aeronautics and Space Administration (NASA) in 1985 using Bureau helium. The *Discovery* space shuttle was launched four times, the *Challenger* and *Atlantis* orbiters were each launched twice, and the *Columbia* made one flight. Each space shuttle launch requires about 7.5 MMcf of helium for purging and pressurizing. Helium demand for space activity is increasing and is expected to increase more when the U.S. Department of Defense's space shuttle facilities at Vandenburg Air Force Base, CA, become operational.

The Federal agencies purchase their major helium requirements from the Bureau of Mines. Direct helium purchases by the U.S. Department of Energy, the U.S. Department of Defense, NASA, and the National Weather Service constituted most of the Bureau's Grade-A helium sales. All of the remaining sales to Federal agencies were through private helium distributors, who purchased equivalent volumes of Bureau helium under contracts described in the Code of Federal Regulations (30 CFR 602). Some of the private distributors also have General Services Administration helium supply contracts. These contracts make relatively small volumes of helium readily available to Federal installations at reduced freight charges.

**Table 4.—Total sales of Grade-A helium in the United States**

(Million cubic feet)

| Year | Volume |
|---|---|
| 1981 | 866 |
| 1982 | 867 |
| 1983 | 995 |
| 1984 | 1,245 |
| 1985 | 1,444 |

**Table 5.—Bureau of Mines sales of Grade-A helium, by purchaser[1]**

(Thousand cubic feet)

| | 1983 | 1984 | 1985 |
|---|---|---|---|
| Federal agencies: | | | |
| Department of Defense | 105,372 | 117,047 | 120,225 |
| Department of Energy | 32,821 | 34,599 | 37,731 |
| National Aeronautics and Space Administration | 37,674 | 49,323 | 103,144 |
| National Weather Service | 874 | 752 | 909 |
| Other | 2,957 | 4,052 | 7,604 |
| Total | 179,698 | 205,773 | 269,613 |
| Federal agency sales supplied by private contract helium distributors[2] | 59,059 | 86,434 | 124,299 |
| Commercial sales | 2,976 | 2,253 | 3,534 |
| Grand total | 241,733 | 294,460 | 397,446 |

[1] Table identifies Federal purchaser, who may redistribute the helium to another Federal helium user.

[2] Purchased from the Bureau of Mines by commercial firms and redistributed to Federal installations under contract authority of 30 CFR 602.

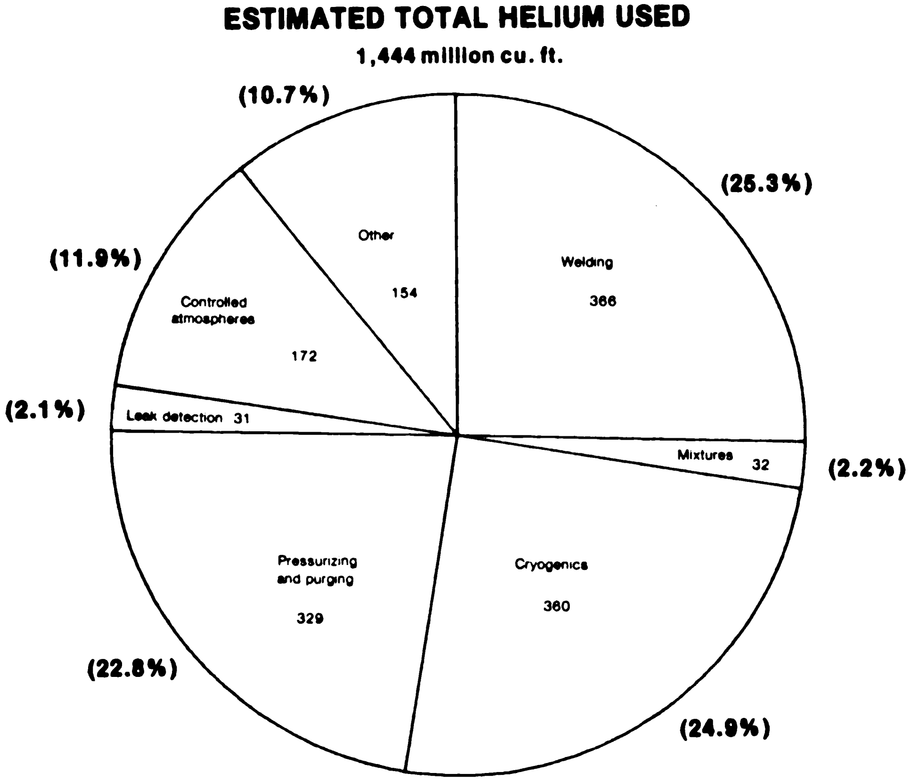

**Figure 3.—Estimated helium consumption in the United States in 1985, by end use (million cubic feet).**

## STOCKS

The volume of helium stored for future use in the Bureau of Mines helium conservation storage system, which includes the conservation pipeline network and the Cliffside Field near Amarillo, TX, totaled more than 37 billion cubic feet (Bcf) at yearend. The conservation storage system contains crude helium purchased by the Bureau under contract, Bureau helium extracted in excess of sales, and privately owned helium stored under contract. During 1985, 488 MMcf of private helium was delivered to the Bureau's helium conservation storage system and 962 MMcf was withdrawn, for a net decrease of 474 MMcf of private helium in storage.

**Table 6.—Summary of Bureau of Mines helium conservation storage system[1] operations**

(Thousand cubic feet)

| | 1983 | 1984 | 1985 |
|---|---|---|---|
| Helium in conservation storage system at beginning of period: | | | |
| Stored under Bureau of Mines conservation program | 35,787,375 | 35,511,661 | 35,196,692 |
| Stored for private producers under contract | 3,475,638 | 2,963,507 | 2,814,606 |
| Total | 39,263,013 | 38,475,168 | 38,011,298 |
| Input to system: | | | |
| Net deliveries from Bureau of Mines plants[2] | -275,714 | -314,969 | -411,681 |
| Stored for private producers under contract | 282,018 | 506,091 | 487,576 |
| Total | 6,304 | 191,122 | 75,895 |
| Redelivery of helium stored for private producers under contract[2] | -794,149 | -654,992 | -961,801 |
| Net addition to system[2] | -787,845 | -463,870 | -885,906 |
| Helium in conservation storage system at end of period: | | | |
| Stored under Bureau of Mines conservation program | 35,511,661 | 35,196,692 | 34,784,996 |
| Stored for private producers under contract | 2,963,507 | 2,814,606 | 2,340,396 |
| Total | 38,475,168 | 38,011,298 | 37,125,392 |

[1] Crude helium is injected into or withdrawn (-) from the Government's underground helium storage facility, a partially depleted natural gas reservoir in Cliffside Field near Amarillo, TX.

[2] Negative numbers denote net withdrawal from storage.

## RESOURCES

Domestic measured and indicated helium resources as of January 1, 1985 (the latest figures available), are estimated to be 504 Bcf. The total identified helium resources are about 20 Bcf more than reported in 1984. This change is due to the identification of additional helium reserves in the Pecos Slope area of New Mexico and an increase in the undefined indicated category. The resources included measured reserves and indicated resources estimated at 240 and 29 Bcf, respectively, in natural gas with a minimum helium content of 0.3%. The measured reserves included 38 Bcf stored in the Bureau of Mines' helium conservation storage system. Measured helium resources in natural gas with a helium content of less than 0.3% are estimated to be 44 Bcf. Indicated helium resources in natural gas with a helium content of less than 0.3% are estimated to be 191 Bcf. Approximately 89% of the domestic helium resources under Federal ownership are in the Riley Ridge area and the Church Buttes Field in Wyoming, and in the Cliffside Field in Texas.

Most of the domestic helium resources are in the midcontinent and Rocky Mountain regions of the United States. The measured helium reserves are in approximately 95 gasfields in 11 States. About 92% of these reserves is contained in the Hugoton Field in Kansas, Oklahoma, and Texas; the Keyes Field in Oklahoma; the Panhandle and Cliffside Fields in Texas; and the Riley Ridge area in Wyoming. The Bureau of Mines analyzed a total of 381 natural gas samples from 27 States during 1985 in conjunction with a program to survey and identify possible new sources of helium.

## TRANSPORTATION

All Grade-A gaseous helium sold by the Bureau was shipped in cylinders, special railway tank cars, or highway tube semitrailers. Liquid helium was shipped in dewars and semitrailers from the Exell helium plant. Private industrial gas distributors shipped helium as gas or liquid. Much of the private helium was transported in liquid form by semitrailers to distribution centers, where a portion was gasified and compressed into trailers and small cylinders for delivery to the end user.

## PRICES

The Bureau of Mines price, f.o.b. plant, for Grade-A helium was increased from $35 to $37.50 per Mcf effective October 1, 1982. The $37.50-per-Mcf price remained in effect throughout 1985. Private producers' price for Grade-A helium was about $36 per Mcf at yearend. The price of liquid helium averaged $55 per Mcf gaseous equivalent, plus possible surcharges.

## FOREIGN TRADE

Exports of Grade-A helium, all by private industry, increased by 12% in 1985 to 439 MMcf (table 7). Over 62% of the exported helium was shipped to Europe. Belgium-Luxembourg, France, and the United Kingdom, collectively, received more than 94% of the European helium imports. About 25% of the U.S. helium exports went to Asia, 4% to South America, 3% to Central America, 2% to North America, 1% to the Middle East and Australia-New Zealand, and less than 0.5% each to Africa and the Caribbean. The shipments of large volumes of helium to Western Europe were attributed to helium's use in breathing mixtures for diving and for welding in the exploration for North Sea oil and gas. Liquid helium is also being used in significant quantities in cryogenic research and superconducting equipment. Although no helium was imported in 1985, import tariffs on helium decreased 0.2% on January 1, 1985, to 4.0%. Future decreases are planned, with the import tariff finally reaching 3.7% on January 1, 1987.

**Table 7.—U.S. exports of Grade-A helium**

(Million cubic feet)

| Year | Volume |
|---|---|
| 1981 | 389 |
| 1982 | 378 |
| 1983 | 368 |
| 1984 | 392 |
| 1985 | 439 |

Source: Bureau of the Census.

## WORLD REVIEW

World production of helium, excluding the United States, was estimated to be 100 MMcf, most of which was extracted in Poland. The remainder was attributed to centrally planned economy countries.

## TECHNOLOGY

Magnetic resonance imaging (MRI) continues to gain acceptance in the medical field. About 125 units were installed during the year, which doubled the units in operation at the end of 1984. MRI utilizes a superconducting magnet cooled by liquid helium to produce a magnetic field. The patient is placed in the magnetic field, where molecules in the body align themselves with magnetic field lines. Radio waves are then beamed through the patient causing a different molecular alignment. When the radio waves are turned off, the molecules oscillate as they attempt to swing back to their prior magnetic alignment. This oscillation generates extremely weak radio waves that are received and analyzed by computer to obtain an image of the inside of the body. MRI and computer-assisted tomography (CAT) scans are now being utilized extensively at U.S. clinics. MRI offers several advantages over older methods of imaging, such as X-rays, as there are no harmful effects associated with this procedure.

Commissioning of Fermi National Accelerator Laboratory's (FNAL) Tevatron/Tevatron 1 is proceeding with the first experiment scheduled for 1986. When the collider begins to function, it will be the highest energy accelerator in the world. If the Tevatron operates as designed, the focus of particle research will shift from the European Center for Nuclear Research (CERN) in Geneva, Switzerland, which presently has the highest energy accelerator, to FNAL in

Batavia, IL. Tevatron/Tevatron 1 is the world's first liquid-helium-cooled superconducting particle accelerator. The Government-owned, contractor-operated project at Batavia, IL, is a major advance in high-energy physics research, and the total system design is a major engineering achievement. The use of superconductivity technology means that less electricity is required, reducing energy requirements, while intense and extremely steady magnetic fields are achieved. This application of superconductivity for the Tevatron demonstrates its commercial value and the reliability of large helium liquefiers and refrigerators. The liquid helium that cools the magnets is supplied by a 5,000-liter-per-hour central helium liquefier coupled to 24 satellite helium refrigerators. It roughly doubles the world's helium liquefying capacity.

Researchers have begun final preparation for a 2-year test program aimed at developing large superconducting magnets for fusion power reactors of the future. Installation of the final magnet in Oak Ridge National Laboratory's International Fusion Superconducting Magnet Test Facility completed the assembly work with testing scheduled to begin in 1986. The facility is designed to simultaneously test six 45-ton, 6- by 10-foot, D-shaped, helium-cooled superconducting electromagnets under conditions simulating a tokamak fusion reactor (a doughnut-shaped chamber for confinement of ionized gas in a magnetic field). The international program includes three magnets from the United States and one each from Japan, Switzerland, and Euratom (a consortium of European countries engaged in atomic research). The test program will allow the U.S. Department of Energy to select the best design for future liquid-helium-cooled superconducting magnets, which will be used in the final nuclear fusion reactor design.

Other technologies that are presently evolving and require helium's unique properties are (1) superconducting magnets used to separate weakly magnetic materials, (2) helium-neon lasers used to detect gas leaks, (3) helium ions used to treat tumors, (4) infrared mapping of infrared emissions in and beyond our galaxy, (5) helium pillow to analyze thermonuclear airbursts, (6) "Strategic Defense Initiative" equipment, such as lasers and surveillance, and (7) new lighter-than-air activities.

High-field design, liquid-helium-cooled superconducting magnets were selected for the proposed "Superconducting Super Collider." Actualization of this project could have an impact on helium usage.

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[1] Chemical engineer, Helium Field Operations, Amarillo, TX.

[2] All helium volumes herein reported at 14.7 pounds per square inch absolute and 70° F.

# Iodine

## By Phyllis A. Lyday[1]

Reported domestic consumption of iodine decreased during 1985. Three producers of crude iodine supplied less than one-half of domestic demand; the remainder was imported. Excess from the National Defense Stockpile remained unavailable for sale but could be bartered for other materials needed to meet goals.

**Domestic Data Coverage.**—Domestic production data for iodine are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the three operations to which a survey request was sent, two responded, representing an estimated 88% of the total production. Production data are withheld to avoid disclosing company proprietary data.

**Legislation and Government Programs.**—The National Defense Stockpile contained 7.4 million pounds of crude iodine valued at $47 million in inventory at yearend. The stockpile goal remained at 5.8 million pounds.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, iodine would be categorized in tier II, and the goal would be 5.5 million pounds of crude iodine. At yearend, this proposal was under consideration by Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

The Federal Emergency Management Agency (FEMA) published a notice to provide guidance to State and local agencies responsible for radiological emergency planning and preparedness regarding the distribution of potassium iodide (KI) for use as a thyroidal blocking agent by the general public in the vicinity of nuclear powerplants.[2] The U.S. Department of Health and Human Services delegated responsibility to the Food and Drug Administration (FDA) to provide guidance to State and local governments on the use of radioprotective substances and prophylactic use of KI to reduce the radiation dose to specific organs, including dosage and projected radiation exposures at which such drugs should be used. Recommendations were that KI could be used during radiation emergencies by people who are likely to receive more than 10 to 20 rad to the thyroid. KI at recommended doses could block at least 90% of radioiodine absorption if the first dose is given shortly before or immediately after exposure to radioiodine, and the drug could block 50% of radioiodine uptake if the first dose was administered within 4 hours after exposure. State and local officials were responsible for establishing a system for informing the public how to use KI, report side effects of the drug, and get treatment for any adverse reactions. FEMA took the position that the predistribution or stockpiling of KI for use by the general public should not be required.

The Federal Radiological Preparedness Coordinating Committee of FEMA published advisory guidelines to State and local governments who, within the limits of their authority, should consider the recommendations in the development of emergency plans and in determining appropriate actions to protect the general public. In summary, the policy recommends the stockpiling or distribution of KI during emergencies for emergency workers and institutionalized persons, but does not recommend requiring predistribution or stockpiling for the general public.[3]

The FDA proposed amending regulations providing for the safe use of elemental iodine, KI, and isopropanol as components of a sanitizing solution produced by the Diversey Wyandotte Corp. for use on food-contact surfaces.[4]

The FDA continued to list Red No. 3 dye, erythrosine, on the provisional list of color additives. Red No. 3 contains 58% iodine by weight and has a grape-like color used in carbonated soft drinks, powdered drinks, gelatin desserts, icings, and pet foods. Although under pressure by one citizens group, the FDA declined to make a final decision on the provisional list until all the relevant issues were considered. Amendments to the Food, Drug, and Cosmetic Act of 1960, the Delaney Clause, required that all permanently listed dyes be proven safe. The FDA announced that a decision on the provisional status was expected to be made in 1986.[5]

## DOMESTIC PRODUCTION

The Dow Chemical Co. continued to recover iodine from mineral-rich brines as a byproduct of bromine and other salts such as sodium, magnesium, and calcium-magnesium compounds. Dow's iodine production decreased during 1985 because of a planned shutdown of brine operations by 1986.

North American Brine Resources operated three miniplants at Dover and Hennessey in Kingfisher County, OK. The plants were located at oilfield reinjection disposal sites. Iodine of 95% purity was produced. Plant capacity was between 260,000 and 350,000 pounds per year. North American was a joint venture among Godoe USA Inc., a wholly owned subsidiary of United Resources Industry Co., 50%; Beard Oil Co., 40%; and Inorgchem Development Inc., a wholly owned subsidiary of Mitsui & Co. USA Inc., 10%.

Woodward Iodine Corp., a subsidiary of Asahi Glass Co. of Japan, produced iodine from brines using the "blowing-out" process. Iodine purity was greater than 99.8%. Plant capacity was reported at 2 million pounds per year.

## CONSUMPTION AND USES

An accurate iodine end-use pattern was not available because intermediate compounds were marketed before reaching their ultimate end uses. The downstream uses of iodine continued to be animal feed supplements, catalysts, pharmaceuticals, sanitary and industrial disinfectants, stabilizers, inks and colorants, photographic equipment, and other uses. Other uses included production of high-purity metals, motor fuels, iodized salt, smog inhibitors, and lubricants. Iodine also had application in cloud seeding and radiopaque diagnosis in medicine.

Deepwater Chemical Co. Inc., sole producer of calcium iodide in the United States, reported a stable market of less than 111,000 pounds.[6]

The U.S. International Trade Commission (ITC) publication, "Synthetic Organic Chemicals, 1984," reported that the Sterling Organic Div. of Sterling Drug Inc. and Mallinckrodt Inc. were the only domestic producers of roentgenographic contrast media used in X-rays. Substances listed as being produced were meglumine diatrizoate, sodium diatrizoate, iopanoic acid, meglumine iothalamate, meglumine, sodium tyropanoate, and an "other" category. These substances contained between 47% and 67% iodine by weight. Sterling discontinued the production of radiopaque compounds in June 1984 and began importing compounds for domestic sales that occurred throughout 1985.

Radioactive iodine-125 was shipped by New England Nuclear Products, an E. I. du Pont de Nemours & Co. Inc. subsidiary, to Daiichi Pure Chemicals Co. Ltd., its exclusive distributor in Tokyo, Japan. Isotopes were used in university and hospital research.

Modern day rainmakers used silver iodide and sometimes dry ice as a nucleating agent to "seed clouds" by attracting cloud droplets to produce rain. About 25,000 pounds of silver iodide was used throughout the world for cloud seeding, including about 1,000 pounds in the United States. The amount used varied but averaged between

10 and 50 grams per cloud seeding. Deepwater Chemical was the sole supplier.

The ITC reported in "Synthetic Organic Chemicals, 1984," that 357,000 pounds of Red No. 3 was sold at a value of $5.2 million. The four companies reporting production were H. Kohnstamm & Co. Inc., Sterling Drug, McCormick & Co. Inc., and Warner-Jenkinson Co.

Several major companies that consume iodine were for sale during 1985. Mallinckrodt, a specialized chemicals and medical products company, was the largest domestic consumer of crude iodine and had been acquired by Avon Products Inc. in 1982 for $715 million. Uniroyal Chemical Co., a subsidiary of Uniroyal Inc., was also for sale. The subsidiary manufactured agricultural and industrial chemicals, specialized rubber and plastic products, and other specialty chemicals. Such catalysts as titanium tetraiodide and diethylaluminum iodide were used to produce stereospecific polybutadiene and polyisoprene, major synthetic rubbers.

**Table 1.—U.S. consumption of crude iodine, by product**

| Product | 1984 | | 1985 | |
|---|---|---|---|---|
| | Number of plants | Consumption (thousand pounds) | Number of plants | Consumption (thousand pounds) |
| Reported consumption: | | | | |
| Resublimed iodine | 4 | 161 | 6 | 191 |
| Potassium iodide | 8 | 1,281 | 8 | 1,077 |
| Sodium iodide | 6 | 122 | 5 | 145 |
| Other inorganic compounds | 15 | 1,286 | 28 | 1,248 |
| Ethylenediamine dihydroiodide | [r]6 | 1,137 | 5 | 1,199 |
| Other organic compounds | 22 | 1,540 | 16 | 1,312 |
| Total | [1]29 | 5,527 | [1]27 | 5,172 |
| Apparent consumption | XX | W | XX | W |

[r] Revised. W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1] Nonadditive total because some plants produce more than one product.

## PRICES

In April, the major suppliers of crude iodine increased prices about 14 cents per pound to $5.72 per pound for truckload quantities; smaller quantities were reported at $6.35 per pound. Silver iodide for cloud seeding was about $2.00 per gram. The quoted yearend U.S. prices for iodine and its primary compounds were as follows:

| | Per pound[1] |
|---|---|
| Calcium iodate, FCC drums, f.o.b. works | $5.50 |
| Calcium iodide, 50-kilogram drums, f.o.b. works | 9.07 |
| Iodine, crude, drums | $5.60- 5.72 |
| Iodoform, N.F., 300-pound drums, f.o.b. works | 24.00 |
| Potassium iodide, U.S.P., granular, crystals, drums, 1,000-pound lots, delivered | 10.72- 12.39 |
| Resublimed iodine, U.S.P., granular, 100-pound drums, works | 14.21- 14.59 |
| Sodium iodide, U.S.P., crystals, 300- to 500-pound lots, drums, freight equalized | 14.72 |

[1] Conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiations and/or somewhat different price quotations.

Source: Chemical Marketing Reporter. V. 228, No. 25, Dec. 16, 1985, pp. 40-48.

## FOREIGN TRADE

The U.S. Department of the Treasury began charging a duty of 6.7 cents per pound on iodine of 99.9% or greater purity in September 1984. Treasury decided to take Japanese-produced iodine imported under item 415.25, Tariff Schedule of the United States (TSUS), and classify it under the provisions for resublimed iodine in item 415.27, TSUS. This decision was based on the various filtering, separating, and heating procedures that used sulfuric acid, hydrochloric acid, and chlorine. Although the product was not resublimed, Treasury considered it to be something other than crude because of further processing. Under the similitude provision, item 798.00, TSUS, it was classified "a nonenumerated product most resembling as to use the product resublimed iodine at the same rate of duty as that applicable to as resublimed iodine."[7]

At yearend 1985, the collection of the duty caused delays in the delivery of iodine while the U.S. Customs Service sent samples to laboratories for analysis. The duty rate during 1985 on crude and resublimed iodine was $0.00 and $0.065 per pound, respectively.

**Table 2.—U.S. imports for consumption of crude iodine, by type and country**

(Thousand pounds and thousand dollars)

| Type and country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value[1] | Quantity | Value[1] |
| Iodine, crude: | | | | |
| Belgium | -- | -- | 21 | 174 |
| Canada | -- | -- | 1 | 3 |
| Chile | 1,176 | [r]5,304 | 1,651 | 8,105 |
| Japan | 3,711 | [r]19,404 | 3,299 | 18,479 |
| Mexico | 179 | 93 | -- | -- |
| United Kingdom | (2) | [r]2 | -- | -- |
| Total[3] | 5,067 | [r]24,803 | 4,971 | 26,761 |
| Iodine, potassium: | | | | |
| Belgium | (2) | 3 | 3 | 17 |
| Canada | (2) | [r]1 | 1 | 3 |
| Germany, Federal Republic of | 3 | [r]26 | 6 | 30 |
| India | 24 | [r]124 | 12 | 64 |
| Italy | 7 | 7 | 2 | 3 |
| Japan | 25 | [r]138 | 41 | 226 |
| United Kingdom | 4 | [r]45 | 2 | 54 |
| Total[3] | 63 | [r]344 | 67 | 396 |
| Iodine, resublimed: | | | | |
| Canada | [r](2) | [r]1 | -- | -- |
| Germany, Federal Republic of | -- | -- | (2) | 4 |
| Japan | (4) | (4) | 408 | 2,158 |
| Mexico | -- | -- | 1 | 13 |
| Sweden | [r]1 | [r]9 | 2 | 17 |
| Total[3] | 1 | [r]10 | 410 | 2,193 |
| Grand total[3] | 5,131 | [r]25,158 | 5,448 | 29,350 |

[r] Revised.
[1] Declared c.i.f. valuation (1984 value previously published as custom value).
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.
[4] Revised to zero.

Source: Bureau of the Census.

## WORLD REVIEW

**Chile.**—María Elena and Pedro de Valdivia, the only remaining nitrate mines in the world, were owned by the Sociedad Química y Minera de Chile (SOQUIMICH). Final products included sodium nitrate, potassium nitrate, sodium sulfate, and iodine. From each 2,000 pounds of caliche ore mined, 75 pounds of potassium nitrate, 13 pounds of sodium sulfate, and 0.2 pound of iodine were produced.[8] María Elena employed about 1,800 workers, and Pedro de Valdivia employed about 2,000 workers.

SOQUIMICH announced the completion of a new iodine plant at yearend 1985 with a capacity between 440,000 and 550,000 pounds per year. Potential iodine reserves were estimated at 300 million pounds of economically recoverable iodine in ore surrounding the existing mining operations, and another 440 million pounds in overburden and waste dumps close to the plants.[9] In addition to the new plant, SOQUIMICH had developed a new mineral fertilizer byproduct, "astrakanite," or bloedite, a magnesium-sodium hydrous sulfate, utilizing residues that were disposed of in the playa for 30 years from the Coya Sur evaporation ponds that concentrate the iodide liquor leached from the nitrates.

**Japan.**—Japan led the world in production of iodine in 1985. Japan produced wet, propane-butane-rich, and dry, methane-rich natural gas, but all of the iodine produced in Japan occurred in the brines in the dry type of gasfields. Production was from various strata buried with natural gas between 1.7 and 24 million years ago. The natural gas reservoirs were found within the sedimentary basin of the marine Kazusa Group of Late Pliocene to Middle Pleistocene in sediments deposited in water about 600 feet or more in depth. The group is distributed over an area of about 12,000 square kilometers. The major iodine-producing area was the southern Kanto Gasfields, which extend into Chiba, Tokyo, and Kanagawa Prefectures. Iodine was produced in the Niigata and Nakajo Gasfields in Niigata Prefecture, on the Sea of Japan side of central Japan, and the Sadowara Gasfield in Miyazaki Prefecture, southern Kyushu. The occurrence of iodine was confirmed in gasfields in southern Okinawa, the Oshamambe, Hokkaido, and the Ishikawi, Honshu.[10]

**U.S.S.R.**—At the Neftechala iodine-bromine plant in Azerbaidzhan, construction of the first stage of renovation was reported completed. At the Nebit-Dag iodine-bromine plant in Turkmens S.S.R. (Turkmenistan), an experimental facility was planned to study extraction of coproduct boron, calcium, magnesium, and sodium compounds from the brines during 1986-90. It was reported that the brines contain 250 grams per liter combined of these various elements.[11]

**Table 3.—Crude iodine: World production, by country[1]**

(Thousand pounds)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Chile | 5,926 | 5,723 | 6,158 | 5,866 | 5,700 |
| China[e] | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| Indonesia | [r]55 | 64 | 55 | 55 | 55 |
| Japan | 15,128 | 15,829 | 16,034 | 16,098 | [3]15,986 |
| U.S.S.R.[e] | 4,400 | 4,400 | 4,400 | 4,400 | 4,400 |
| United States | W | W | W | W | W |
| Total[4] | [r]26,509 | 27,016 | 27,647 | 27,419 | 27,141 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1] Table includes data available through June 17, 1986.

[2] In addition to the countries listed, New Zealand also produces elemental iodine, but production data are not available, and available information is inadequate for formulation of reliable estimates of output levels.

[3] Reported figure.

[4] Excludes U.S. production.

## TECHNOLOGY

The National Oceanic and Atmospheric Administration reported in 1984 that there were 32 domestic cloud-seeding projects covering 66,120 square miles. Cloud seeding was accomplished in two ways. In the first method, silver iodide, dissolved by ammonium iodide, was sprayed into a cloud through a propane flame, usually from the wing of an airplane flying through or just below a cloud. In the second method, an aluminum canister containing a pyrotechnic mixture of silver iodide, silver iodate oxidizer, aluminum, and magnesium was used. The canister, attached to an airplane wing, was ignited electrically, thus releasing the iodide particles. The canister could also be dropped through the cloud.[12]

Recent experiments demonstrated the silver ions diffuse rapidly when a potential was applied across a silver mercury iodide solid electrolyte. At temperatures less than 50° C, silver mercury iodide existed in an ordered structure. At temperatures equal to and above 50° C, the cations demonstrated a disordered structure. Although details differ from one compound to another, most crystalline inorganic electrolytes followed a similar temperature pattern described from silver mercury iodide. Each had a low-conductivity phase in which ions were ordered in a subset of lattice sites. Over some higher temperatures, the ions became disordered among the sites and conductivity was high. This predictable behavior has guided solid-state chemists searching for new high-conductivity solid electrolytes. High-conductivity solid electrolytes have revolutionized conventional concepts of ionic compounds and have potential in high-energy-density battery and fuel cells and lasers.[13]

An organic material, named ET-iododibromide, that becomes superconducting at 2.8 kelvin (K) and ambient pressure has been produced. The transition temperature is twice as high as the level achieved by earlier organic superconductors at ambient pressure. Evidence indicates that this compound can become superconducting at 4 K under different pressure conditions.[14]

The 28th biennial Kirkpatrick Chemical Engineering Achievement Award was bestowed on Tennessee Eastman Co. for pioneering a coal-based acetic anhydride process that offers lower costs using a rhodium, methyl iodide, and lithium catalyst. The firm was the first to manufacture an industrial chemical that used a second-generation coal-gasification process to produce acetic anhydride, a key raw material.[15]

Studies of two strains of chickens genetically susceptible to autoimmune thyroiditis indicate a direct link between the rising incidence of autoimmune thyroiditis in chickens and their consumption of large amounts of iodine. The research can be applied to similar incidents of autoimmune thyroiditis in Americans and their consumption of large amounts of iodine. When iodine concentrates in the thyroid, it is incorporated into thyroglobulin molecules, altering the shape of the molecules and probably increasing their immunogenicity. This may account for the initiation of autoimmune disease.[16]

Iodophors, carriers of iodine, are the least expensive way to sterilize water. Starch and iodine solutions are capable of annihilating bacterial flora, yeasts, and molds. Polyvinyl alcohol and iodine are also other common antiseptic bases. In addition, the same type of starch and iodine solution can be used to preserve fruit for several months.[17]

Energy-efficient lamps containing iodine in metal halide compounds were developed specifically for the Statue of Liberty by General Electric Co.'s Lighting Business Group. The lamps are activated by passing current through a quartz tube and exciting the metal halides to higher energy levels. The colors depend on the chemical makeup of the iodine compounds. The expected consumption of 17.9 kilowatt hours per year will result in a savings of over 50% of the cost of the electricity.[18]

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[1] Physical scientist, Division of Industrial Minerals.

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[18] Engineering News-Record. Better Statue Lights for Less. V. 215, No. 14, 1985, p. 15.

# Iron Ore

## By Peter H. Kuck[1]

U.S. production of iron ore declined slightly in 1985, as the recovery of the basic industries sector from the 1982-83 recession began to slow. Demand for pellets from the iron and steel industry leveled off in midyear compared with 1984 levels, but firmed in the fourth quarter. The domestic ore industry suffered from excess production capacity and was forced to schedule a number of shutdowns ranging from 4 to 15 weeks as well as production cutbacks. One mine was closed and the future of several others was uncertain. Both the ore and steel industries underwent more restructuring as part of the continuing struggle since 1982 to reduce production costs and improve efficiency. Production of usable ore in 1985 was about 56% of productive capacity. Yearend stocks of iron ore at U.S. docks and furnace yards were at their lowest levels in more than 30 years.

In the rest of the world, iron ore production and trade were slightly higher in 1985 as consumption stabilized in both the European Communities (EC) and Japan. New markets for ore from market economy countries continued to grow in China, the Republic of Korea, Taiwan, Eastern Europe, and the Middle East. Nevertheless, worldwide overcapacity remained a serious problem for most producers and was expected to worsen when the 34-million-ton-per-year[2] Carajás project in Brazil, the 7.4-million-ton-per-year Kudremukh project in India, and the 4.9-million-ton-per-year San Isidro Mine in Venezuela are brought into full production. International iron ore prices firmed, while ocean freight rates for spot charterings, in constant dollars, declined to their lowest levels in 7 years.

**Table 1.—Salient iron ore statistics**

(Thousand long tons and thousand dollars unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Iron ore (usable,[1] less than 5% manganese): | | | | | |
| Production | 73,174 | 35,433 | 37,562 | 51,269 | 48,751 |
| Shipments | 72,181 | 35,756 | 44,596 | 50,883 | 49,411 |
| Value | $2,915,239 | $1,491,809 | $1,944,988 | $2,247,686 | $2,076,730 |
| Average value at mines dollars per ton | $40.39 | $41.72 | $43.61 | $44.17 | $42.03 |
| Exports | 5,546 | 3,178 | 3,781 | 4,993 | 5,033 |
| Value | $244,685 | $150,522 | $182,744 | $239,257 | $240,557 |
| Imports for consumption | 28,328 | 14,501 | 13,246 | 17,187 | 15,771 |
| Value | $947,977 | $470,847 | $445,731 | $529,065 | $452,240 |
| Consumption (iron ore and agglomerates) | 104,385 | 63,916 | 70,629 | 72,514 | 70,575 |
| Stocks, Dec. 31: | | | | | |
| At mines[2] | 12,734 | 12,129 | [3]4,122 | [3]5,265 | [3]5,951 |
| At consuming plants | 36,203 | 29,923 | 25,494 | 24,017 | 21,290 |
| At U.S. docks | 6,571 | 5,750 | 3,174 | 2,942 | 2,404 |
| Manganiferous iron ore (5% to 35% manganese): | | | | | |
| Shipments | 156 | 28 | 30 | 79 | 18 |
| World: Production | [r]844,606 | [r]768,011 | 726,399 | [p]817,428 | [e]845,251 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Direct-shipping ore, concentrates, agglomerates, and byproduct ore.

[2] Excludes byproduct ore.

[3] These stocks are not comparable to those of previous years owing to the reclassification of some stocks from the usable to the byproduct category.

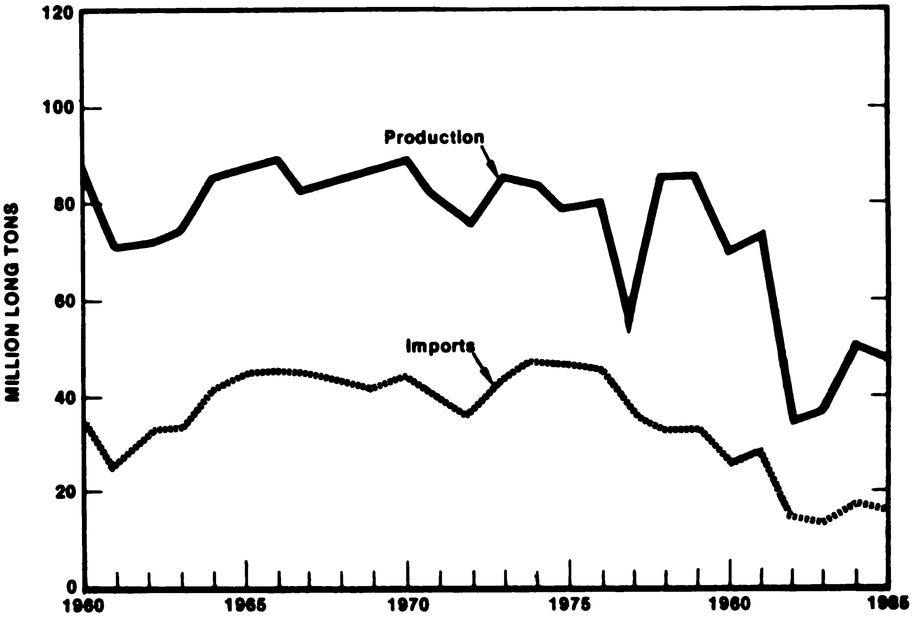

Figure 1.—U.S. iron ore production and imports for consumption.

**Domestic Data Coverage.**—U.S. production data for iron ore are developed by the Bureau of Mines from three separate voluntary surveys of domestic operations. The annual "Iron Ore" survey (1066-A) provides the basic data used in this report. Of 55 addressees to whom the 1066-A form was sent, 52 responded, representing 78.3% of total production shown in tables 1 through 4. Production for nonrespondents to the annual survey was estimated from monthly surveys (1066-M), using data from railroad reports and reported production levels in prior years, supplemented by employment data, mine inspection reports, and information from consumers. Consumption data were mostly provided by the annual "Blast Furnace and Steel Furnace" survey (1067-A). Data coverage for this survey is reported in the "Iron and Steel" chapter.

## EMPLOYMENT

Statistics on employment and productivity in the U.S. iron ore industry in 1985, shown in table 2, were derived from quarterly employment data supplied by the Mine Safety and Health Administration (MSHA) of the U.S. Department of Labor, and from production data derived from Bureau of Mines surveys. Both sets of data were obtained from producers' reports.

The statistics include production workers employed at mines, concentrators, and pelletizing plants, and in repair and maintenance shops, but do not include 1,014 persons engaged in management, research, or office work at mines and plants. Employees engaged in ore preparation, such as sintering, at blast furnace sites are not included. Because employment data reported to MSHA are primarily for safety analysis, hours spent by salaried employees in mines or plants may be included by operators in the total number of hours worked at individual mines or plants. This has resulted in understatement of calculated productivity by 10% to 25% for some operations, but its effect on others is not known. If company reporting practice is consistent, however, comparison of productivity from 1 year to the next should be reasonably valid.

Average quarterly employment decreased slightly compared with that of 1984, with total hours worked and output of usable ore decreasing by 16% and 5%, respectively. In the Lake Superior district, which accounts for the bulk of U.S. output, average productivity for usable ore was only 14% higher than that of 1984 but 59% higher than that of 1981. The significant gain since 1981 is the result of drastic reductions in employment made by the principal producers in 1982, which have allowed the potential productivity of highly mechanized operations to be increasingly realized. The concentration of production in large-scale taconite operations of the Lake Superior district was an important contributing factor.

## DOMESTIC PRODUCTION

A leveling off of demand from the iron and steel industry in midyear was largely responsible for the 5% decline in iron ore production from the 1984 level of 51.3 million tons. A small increase in demand from Canada helped moderate the decline. Output of usable ore in the first half of the year was 8% lower than that in the comparable period of 1984, shipments were down 6%, and production of pig iron decreased 10%. In August, demand began to recover and, during the last 5 months of the year, monthly production of pig iron was above 1984 levels. Several mines and pelletizing plants were closed for periods of 4 to 15 weeks during the second half of the year. By December 1, four of the eight taconite operations in Minnesota had been shut down for an indefinite period, and one had been permanently closed. The patterns of production, shipments, and plant closings were similar to those experienced in 1984 and reflected a continuing weakness in demand for domestic iron and steel. Total output of usable ore was equivalent to about 56% of installed production capacity on January 1.

Iron ore was produced by 19 open pit mines and 1 underground mine. Fifteen mines produced ore for the iron and steel industry but only 2 mines were operated throughout the year and only 1 of the 2 produced at its rated capacity. One taconite mine and associated pelletizing plant remained idle, while one large, permanently closed "natural ore" mine shipped pellets and concentrates from stocks. Installed production capacity for usable ore at yearend was estimated at 86 million tons per year, including 82 million tons of capacity for pellets. Effective production capacity for pellets was at least 15 million tons less than installed capacity.

An average of 3.1 tons of crude ore was mined in 1985 for each ton of usable ore produced. This ratio does not take into account the tonnage of waste rock or overburden removed. The ratio of total materials mined to usable ore produced was probably greater than 5 to 1. Low-grade ores of the taconite type mined in Minnesota and Michigan accounted for 97.9% of total crude ore production. U.S. production of pellets totaled 47 million tons in 1985, 96% of usable ore output. Average iron content of usable ore produced was approximately 64.2%, while that of usable ore shipped was 63.8%.

Inland Steel Co. combined the activities of its former Raw Materials Department (iron ore, coal, limestone, and fleet operations) with those of its coke, ironmaking, and materials control operations to form a new Materials and Energy Group. The company continued to restructure its iron ore operations in order to reduce costs and match the downsizing of its steelmaking operations. Inland Steel retained its wholly owned Minorca Mine and pelletizing facilities at Virginia, MN, along with its shares in the Empire Mine at Palmer, MI, and the Wabush Mines operations in Labrador and at Pointe Noire, Quebec. However, the Butler Taconite project, in which Inland Steel has 38% ownership, was permanently closed on June 29.

The closure of the Butler Taconite project at Nashwauk, MN, was the first permanent shutdown among the eight taconite operations on the Mesabi Range. Butler Taconite had an annual production capacity of 2.7 million tons of pellets. The decision to close was precipitated by the bankruptcy filing in April of Wheeling-Pittsburgh Steel Corp., which owned 24.5% of the venture. The remaining 37.5% share was held by The M. A. Hanna Co. (formerly Hanna Mining Co.), which managed the project. With the closure of Butler Taconite, Hanna no longer has ownership in any operating U.S. iron mine. As recently as 1980, Hanna was among the leading iron ore producers and merchants in the United States. However, the company continues to manage the National Steel Pellet Co. project at Keewatin, MN. Hanna is also manager and a major shareholder of the Iron Ore Co. of Canada, the largest iron ore producer in Canada, as well as a major shareholder in Minerações Brasileiras Reunidas S.A.

(MBR), the second largest iron ore producer in Brazil.

Minnesota produced 72% of the national output of usable ore in 1985. Production of pellets totaled 33.4 million tons, equivalent to about 53% of installed production capacity of the State's eight taconite plants. The remainder of the output consisted of hematite concentrates produced from "natural" ores by LTV Steel Co. and Rhude & Fryberger Inc. Pittsburgh Pacific Co. shipped 29,000 tons of concentrates recovered from stockpiled ores. All of the taconite plants were operated in 1985 but most were idle for part of the year.

National Steel Pellet was operated throughout the year, except for a 21 day period in April and produced 4.4 million tons of pellets, a level slightly lower than that of 1984. However, in mid-December, the company announced that it would close for a total of 3 months in 1986 because of a planned cutback to 4.0 million tons.

Butler Taconite was operated from March 4 until June 29, when it was permanently closed. During the 4-month period, the operation produced about 960,000 tons of pellets. Approximately 450 employees were affected by the closure.

Reserve Mining Co., a joint venture of Armco Inc. and LTV Steel, recalled an additional 145 employees on January 6 and restarted the second of eight pelletizing lines at its Silver Bay plant. Ore was provided by the Peter Mitchell Mine at Babbitt. The company had been operating only one of its lines since September 1984 when production was cut and 200 employees were laid off. Both lines remained in operation until June 30, when Reserve shut down both Silver Bay and Babbitt for 4 weeks and temporarily laid off 1,000 employees. The company produced only 3.2 million tons during the year, slightly less than 33% of capacity.

Erie Mining Co. resumed production of pellets at Hoyt Lakes on March 3, after a 3-month shutdown, and produced 5.0 million tons before being shut down again on November 30.

Hibbing Taconite Co. was operated from March 17 to October 26 and produced 5.1 million tons of pellets, about 18% less than in 1984.

The Minntac facility of United States Steel Corp. was operated from January 13 to June 30 and from July 28 to December 1, producing about 9.9 million tons of pellets or 53% of installed capacity. The pelletizing plant operated only three of its seven production lines, as in 1984. The work force varied from 1,450 to 1,700 and was somewhat smaller than before owing to streamlined operations.

Oglebay Norton Co. suspended production at Eveleth Mines on June 30 for 15 weeks because of reduced demand for pellets. Only 735 of the 750 laidoff workers were recalled when operations were resumed on October 13. Because of the summer shutdown, Eveleth produced only 3.0 million tons, 50% of capacity. A 380,000-ton production run was made at Eveleth Mines' Fairlane plant using the organic compound "Peridur" as a substitute pellet binder. These lower silica pellets were used by two of the operation's partners in closely monitored blast furnace trials with encouraging results.

The Minorca Mine of Inland Steel Mining Co. was operated from February 24 to June 29 and from August 4 to November 16, producing 1.9 million tons of pellets. Approximately 405 workers were laid off when the mine and pelletizing facilities were temporarily shut down in November. The shutdown was triggered by cutbacks in steel production at Inland Steel's Indiana Harbor Works, which uses Minorca pellets exclusively. Only five of the nine blast furnaces at Indiana Harbor were running at the end of December.

More than 4,500 employees were out of work in Minnesota at yearend as a result of the permanent closure of Butler Taconite and the temporary shutdowns in the fourth quarter of four other taconite plants.

Michigan produced 26% of the national output of usable ore in 1985. Production consisted entirely of pellets produced from ores mined at the Empire and Tilden Mines in Marquette County. Both mining ventures are managed and partially owned by the Cleveland-Cliffs Iron Co. (CCI). The company's wholly owned Republic Mine remained idle throughout the year. Production of pellets totaled 12.5 million tons, of which 6.9 million tons was produced at the Empire plant and 5.6 million tons was produced at Tilden. The Empire facility was operated all year except for a 7-week period between September 1 and October 20 and produced at 86% capacity. The average operating rate at Tilden was only 70%. CCI was forced to suspend all operations at the Tilden Mine and temporarily lay off 850 employees after a fire extensively damaged the mine's main conveyor system on June 12. On July 7, 300 workers were called back and assigned to stripping operations and maintenance. Full operations were resumed on July 29.

In Missouri, Pea Ridge Iron Ore Co. produced about 1.1 million tons of iron ore products, including 1.03 million tons of self-fluxing olivine pellets, from magnetite ore produced at its underground mine near Sullivan. The mine and plant, wholly owned by St. Joe Minerals Corp., were operated throughout 1985.

In Wyoming, Universal Equipment Co. purchased the Atlantic City iron mine from U.S. Steel. The sale included iron ore processing facilities, mining equipment, water rights, and a 76-mile railroad line from the mine to Winton Junction near Rock Springs. Universal Equipment will mine the site for road construction materials. U.S. Steel halted mining operations at Atlantic City in October 1983 and officially closed the mine on April 1, 1984.

## CONSUMPTION AND USES

Consumption of iron ore was about 3% less than that of 1984, owing to decreased demand from the iron and steel industry. Consumption for ironmaking and steelmaking totaled about 63.7 million tons, including 54.7 million tons in blast furnaces, 8.3 million tons in sintering plants, 0.2 million tons each in steelmaking furnaces and for production of direct-reduced iron (DRI), and 0.3 million tons for miscellaneous and unspecified purposes. Consumption of iron ore for manufacture of cement, heavy-medium materials, pigments, and miscellaneous products was approximately 1.2 million tons.

In the iron and steel industry, monthly consumption of ore averaged 5.3 million tons, compared with 5.5 million tons in 1984. The decrease in consumption occurred mainly in the first half of the year. Between January 31 and June 30, the number of operating blast furnaces actually increased from 49 to 53 to meet the traditional seasonal increase in demand for pig iron. Monthly consumption during the 6 months averaged 5.5 million tons and reached a peak of 6.0 million tons in May. In June, however, demand for ore began to slide. By September, monthly consumption had fallen to 4.9 million tons and remained low for the rest of the year. Consumption of ore for the second half averaged 5.1 million tons, with only 43 blast furnaces operating at the end of October. During the last 2 months of 1985, 4 additional blast furnaces were brought on-line, bringing the total at yearend up to 47.

Consumption of iron ore and agglomerates reported by integrated producers of iron and steel totaled 69.4 million tons, including 50.8 million tons of pellets, 16.5 million tons of sinter, and 2.1 million tons of natural coarse ore. Of the primary ore consumed, an estimated 72% was of domestic origin, 14% came from Canada, and 14% came from other countries.

Estimated consumption of other materials in sintering plants included 3.0 million tons of mill scale, 1.4 million tons of flue dust, 3.6 million tons of limestone and dolomite, 1.3 million tons of slag and slag scrap, and 0.8 million tons of coke breeze. Other iron-bearing materials charged directly to blast furnaces included about 74,000 tons of manganiferous iron ore, 1.2 million tons of steel-furnace slag, 0.3 million tons of mill scale, and 1.0 million tons of slag scrap.

## STOCKS

Stocks of iron ore and agglomerates reported at U.S. mines, docks, and consuming plants at yearend continued to decline in 1985 and were at their lowest level in more than 30 years. The decline of 8% in total stocks from that of 1984 was due primarily to a reduction of stocks of imported ore at U.S. docks and furnace yards. Stocks reported at these facilities at yearend included 18.5 million tons of domestic ores, 3.0 million tons of Canadian ores, and 2.2 million tons of other foreign ores. Mine stocks at yearend were about 13% higher than those of 1984, as the quantity of ore shipped from most Minnesota mines was less than production.

End-of-month stocks reported at mines peaked at 13.4 million tons in April and declined to 6.0 million tons at yearend, while stocks of ore reported at consuming plants ranged from a low of 13.8 million tons in March to a high of 21.3 million tons in December. As in previous years, these variations were principally caused by the seasonal nature of ore shipping on the Great Lakes.

Stocks of unagglomerated concentrates reported at pelletizing plants totaled 331,000 tons at yearend. This material is not included in mine stocks of usable ore reported in the accompanying tables because it is considered an intermediate product. Also, mine stock data after 1983 do not include byproduct ore, owing to the change in classification reported in this publication in 1983; data for previous years remain unchanged to avoid disclosing company proprietary information.

## TRANSPORTATION

Vessel shipments of iron ore from U.S. ports on the upper Great Lakes totaled 44.2 million tons, about 4% less than those of 1984. Nearly 90% was destined for U.S. consumers and the rest was destined for Canada. Shipments of iron ore through the St. Lawrence Seaway to U.S. ports on the Great Lakes totaled approximately 4.8 million tons and accounted for about 30% of U.S. imports. The balance of imports, about 11.0 million tons, was shipped through ports on the east and gulf coasts.

Ore shipments from four of the seven U.S. ports on the upper Great Lakes declined from the levels of 1984, with the largest decrease at Superior, WI. Shipments from Two Harbors, Taconite Harbor, and Marquette increased. Tonnage shipped from each port in 1985 was as follows:

| Port | Date of first shipment | Date of last shipment | Total tonnage (thousand long tons) |
|---|---|---|---|
| Duluth, MN | Apr. 2 | Dec. 15 | 6,133 |
| Two Harbors, MN | Apr. 3 | Dec. 21 | 8,719 |
| Silver Bay, MN | Apr. 7 | Dec. 14 | 3,426 |
| Taconite Harbor, MN | Apr. 5 | Dec. 21 | 4,972 |
| Superior, WI | Apr. 5 | Dec. 22 | 8,506 |
| Marquette, MI | Apr. 3 | Jan. 4 | 5,071 |
| Escanaba, MI | Mar. 28 | Dec. 26 | 7,385 |
| Total |  |  | 44,212 |

Source: Lake Carriers Association, 1985 Annual Report.

The number of vessel shipments from all seven ports totaled 1,283, indicating an average cargo of 34,460 tons. Individual cargoes of 60,000 tons or more were loaded at six of the ports during the year, although the average shipment from individual ports ranged from 24,264 tons at Marquette to 60,107 tons at Silver Bay. Relatively high water levels in Lakes Michigan and Superior permitted record loadings of iron ore at Escanaba and Silver Bay. The largest cargo shipped during the year was 69,701 tons, an all-time high for the Great Lakes, loaded on Bethlehem Steel Corp.'s 1,000-foot carrier *Lewis Wilson Foy* at Escanaba for delivery to Indiana Harbor. A record high cargo of 64,188 tons was loaded on Oglebay Norton's *Columbia Star* at Silver Bay for transit through the Soo Locks to Toledo, OH. Previous records were about 68,000 tons at Escanaba and 63,000 tons at Silver Bay, both set in 1983.

Lake freight rates for iron ore, in effect since April 1984, were as follows, per ton: from the Head of the Lakes to lower lake ports, $7.41; from Marquette to lower lake ports, $6.11; from Escanaba to Lake Erie ports, $5.64; and from Escanaba to lower Lake Michigan ports, $4.45.

Published bulk vessel freight rates from the Gulf of St. Lawrence to Lake Erie and Lake Michigan were $5.00 and $7.00 per ton, respectively. Freight rates for self-unloading vessels were $1.50 per ton higher. These rates may include toll charges on the St. Lawrence Seaway, which amount to about $1.24 per ton.

The collapse of a 150-foot section of the west wall of Lock 7 in the Welland Canal blocked shipping on the St. Lawrence Seaway between Lakes Erie and Ontario from October 14 to November 7. By the time repairs were made and the lock was reopened, 118 vessels were waiting for transit, including 12 carrying iron ore from eastern Canada to U.S. lake ports. Although the closure did not cause significant shortages of iron ore at U.S. blast furnaces, and all waiting vessels were locked through by November 12, the delay called attention to the vulnerability of Seaway shipping to damage or obstruction of each of the many locks, bridges, or narrow channels that control navigation along the 1,340-mile route between Duluth and Montreal.

The principal issues concerning U.S. lake shipping in 1985 were proposed construction of a second Poe-class lock at Sault Ste. Marie, and proposed taxes (user charges) on shippers to recover the costs of operation and maintenance of shipping facilities and most of the costs of new construction, which historically have been paid by the Federal Government.

As a result of the construction of 13 self-unloaders with a length of at least 1,000 feet in the last 14 years, and the retirement of smaller vessels, about one-third of the vessels in the U.S. Great Lakes fleet (comprising more than one-half of the fleet's carrying capacity) must use the Poe Lock to transit the St. Mary's River Canal. A malfunction of this lock could seriously disrupt lake shipping and increase costs. The cost of converting the aging and narrow Sabin and Davis Locks into a new Poe-sized lock was estimated to be $227 million. The U.S. Army Corps of Engineers, which has studied the problem for many years, issued a feasibility report on March 29 recommending construction of a second lock that could accommodate all vessel sizes in the fleet.

Although the Lake Carriers' Association advocated construction of the new lock at Sault Ste. Marie, it was opposed to the imposition of user charges. The Office of Management and Budget has proposed that the Congress levy both Port User Charges and U.S. Coast Guard User Charges. The port tax would be used to defray the costs of channel dredging and other harbor maintenance, while the Coast Guard tax would help pay for icebreaking, navigational aids, and vessel documentation. The proposed port tax alone could cost lake shippers more than $4 million annually; charges for new construction would greatly increase this figure. According to the Association, taxes of this magnitude would be an unfair burden on the lake shipping industry. Although the Association remains adamantly opposed to the proposed Coast Guard tax, it has reluctantly agreed to work with the Congress and the Administration to develop an equitable port charge in the form of an ad valorem tax on cargo that would be assessed only once and paid by the shipper. Proponents of the user charges feel that costs of shipping facilities should be largely borne by the shippers instead of by the Federal Government.

Published railway freight rates for pellets from mines to upper lake shipping ports increased in Minnesota in 1985 but were essentially unchanged in Michigan, compared with rates in late 1984. On April 1, the rate for pellets from the western Mesabi Range to the Allouez docks at Superior, WI, was raised from $4.87 to $4.96 per ton. On June 3, the rate was increased an additional $0.03 to $4.99. For pellets from the Marquette Range of Michigan, the rates to Presque Isle and Escanaba were $2.40 and $2.68 per ton, respectively. Dock charges at Duluth, Superior, and Escanaba ranged from 64 to 92 cents per ton. At Lake Erie ports, ore transfer charges from rail-of-vessel or dock receiving area direct into railway cars ranged from about $0.96 to $1.15 per ton, up slightly from those of 1984. Most rail rates from lower lake ports to consuming districts were also unchanged; the volume rate from Lake Erie ports to the Pittsburgh and Wheeling districts was $10.16 per ton. Single-car rates for ore imported through east coast ports to inland consuming points were mostly unchanged. The rate to Pittsburgh from Baltimore and Philadelphia remained at $14.93 per ton. All-rail rates from mines to consuming points rose in several instances. However, the volume rates to Granite City, IL, from the Mesabi Range and from Pea Ridge, MO, were unchanged at $18.82 and $6.41 per ton, respectively. The published volume rate to Geneva, UT, from the Mesabi Range was $41.03 per ton. All-rail shipments of pellets from Minnesota by the Duluth, Missabe and Iron Range Railway and connecting lines totaled 1.5 million tons; the greater part of this tonnage was shipped to Geneva, UT, from the Minntac plant.

Published nominal ocean freight rates for iron ore from eastern Canada to U.S. east coast ports were $3.50 to $3.75 per ton, but spot rates quoted for cargoes of 50,000 to 60,000 tons ranged from $1.85 to $3.80 per ton. A few shipments reported from Brazil to east coast ports indicated freight rates of $4.50 to $5.50 per ton.

## PRICES

Producers' published prices for Lake Superior iron ores in the first 7 months of 1985 were unchanged from those quoted in August 1983. The pellet prices thus ranged from 80.5 cents to 86.9 cents per long ton unit (ltu) of iron, natural, delivered rail-of-vessel at lower lake ports, with the lower price quoted by Pickands Mather & Co. and the higher price quoted by CCI, Hanna, Oglebay Norton, and U.S. Steel. The range in unit price was equivalent to approximately $50.71 to $54.75 per long ton of pellets containing 63% iron.

Late in 1984, Mineral Services Inc. (MSI) of Cleveland, OH, began offering pellets at a published price of 66 cents per ltu, on the same basis as the producers' prices. Although the source of pellets was not identified, the company said that at least 2 million tons per year would be available. This was the first time that a nonproducer had publicly quoted a price for Lake Superior pellets since commercial pellet production began in the district in 1955. The MSI price was equivalent to about $41.58 per ton of pellets containing 63% iron.

On August 1, 1985, Pickands Mather effectively lowered its pellet price while changing its price base from the traditional "lower lake port" to "upper lake port," thus transferring charges for lake freight and some handling operations to the buyer. The new quotation was 59.4 cents per ltu of iron, natural, delivered to hold of vessel at upper lake port. Although not specified by the company, the net reduction in price appeared to be about 12%, taking into account published lake freight rates and unloading charges. Inland Steel Mining later adopted the new price base and began quoting an identical price.

On August 16, U.S. Steel switched its price base from natural ltu to dry ltu. The new, effectively lower, price of Minntac pellets was 72.5 cents per dry ltu of iron, delivered rail-of-vessel at lower lake ports. Three weeks later, on September 1, MSI lowered its pellet price from 66 cents to 58 cents per natural ltu of iron, delivered at lower lake ports. At yearend, there were at least three different published price bases being used by Lake Superior producers. The range of prices was approximately equivalent to $37.12 to $55.62 per ton of pellets containing 64% iron, delivered rail-of-vessel at lower lake ports. The departures from traditional pricing and individual price cuts were believed to reflect declining production costs as well as increasing competition between domestic and foreign producers in the U.S. market.

Published prices for other Lake Superior ores, per ton, basis 51.5% iron, natural, delivered rail-of-vessel at lower lake ports, remained as follows: Mesabi non-Bessemer ore, $30.03 for coarse ore and $31.53 for fines; and manganiferous ore, $32.78. CCI continued to quote a price of $28.75 for Old Range non-Bessemer ore, based on rail and lake freight rates and handling charges in effect on April 27, 1981. These prices were not very significant because most Mesabi non-Bessemer ore was produced and consumed by LTV Steel, and little or none of the other grades of ore was produced. Pellets made up more than 98% of ore shipped from the Lake Superior district.

Prices for most Canadian and other foreign ores marketed in the United States were not available. The published price of Wabush pellets, f.o.b. Pointe Noire, Quebec, remained at 63.5 cents per ltu. The average f.o.b. value of all Canadian ores imported by the United States, as determined from data compiled by the Bureau of Census, was $38.01 per long ton. Data from this source indicated average f.o.b. values of $14.05 per ton for Liberian ores and $19.42 per ton for Brazilian ores. Other sources indicated that most imported Canadian ore consisted of pellets; Liberian ores consisted of fines and washed lumpy ore; and about two-thirds of the ore imported from Brazil consisted of pellets. F.o.b. value data for Venezuelan ores were not determinable, because much of the ore was apparently valued on a c.i.f. basis.

Published f.o.b. prices for DRI were also unchanged from those quoted in 1984, and were as follows, per metric ton: at Georgetown, SC, $125 to $135; at Contrecoeur, Quebec, $115; and at Point Lisas, Trinidad, $120. The apparent f.o.b. value of some shipments of DRI imported from Venezuela ranged from about $75 to $102 per long ton.

## FOREIGN TRADE

U.S. exports of iron ore were only slightly higher than those of 1984, because of a leveling off of demand from the Canadian steel industry. Virtually all exports consisted of pellets shipped via the Great Lakes to Canadian steel companies that are partners in U.S. taconite projects in Minnesota and Michigan. Consumption of iron ore at Canadian blast furnaces totaled 13.3 million tons, an amount identical to that of 1984.

U.S. imports of iron ore decreased 8% in 1985, partially reversing the 1984 gain of 30%. Tonnage decreased by 1.4 million tons compared with that of 1984. A sharp decline of ore imports into the Cleveland and Baltimore customs districts accounted for essentially all of the decrease. Imports from Canada fell 24% from the 1984 level, but still accounted for more than one-half of total U.S. imports. Imports from Liberia and Venezuela rose 26% and 36%, respectively, while those from Brazil were unchanged. Brazil, the next largest supplier after Canada, retained its 16% share of U.S. imports.

On December 20, 1984, Pickands Mather, Oglebay Norton, CCI, and the United Steelworkers of America petitioned the U.S. International Trade Commission (ITC) for countervailing duties on imports of iron ore pellets from Brazil. The petitioners said that subsidies granted by the Brazilian Government allow Brazilian pellets to be delivered to U.S. consumers for at least 30% less than pellets produced in the United States, causing injury to the U.S. iron ore industry and particularly to U.S. merchant producers. Cia. Vale do Rio Doce (CVRD), through its U.S. subsidiary, Rio Doce America Inc., responded for Brazil.

U.S. imports of iron ore from Brazil in 1984 totaled 2.5 million tons, including an estimated 1.8 million tons of pellets. The pellet imports equaled an estimated 4% of U.S. consumption, but the petitioners stated that this quantity was equivalent to about 30% of the amount available for sale by U.S. merchant producers. CVRD claimed that it did not need subsidies to compete in the U.S. market because the high grade of its ore allowed pellets to be made in Brazil for about $20 per ton less than what it cost U.S. producers. CVRD also stated that 75% of its 1984 pellet sales in the United States were under long-term contracts to U.S. Steel and Armco, and that about one-half of the remainder was sold in areas of the United States where U.S. pellets could not compete because of high transportation costs. Armco is the principal shareholder in Eveleth Mines, a Minnesota producer operated by Oglebay Norton. U.S. Steel operates the largest pelletizing facility in Minnesota.

On January 28, 1985, the ITC unanimously agreed there was a reasonable indication that imports of Brazilian pellets were materially injuring U.S. pellet producers. The case was referred to the U.S. Department of Commerce on February 4 for investigation of the alleged subsidies granted to Brazilian producers and for recommendation of a countervailing duty. On March 19, Commerce recommended that an ad valorem duty of 5.15% be imposed on Brazilian pellets. This recommendation automatically returned the case to the ITC for a final decision. However, the countervailing duty investigation was suspended on May 29, following agreement by CVRD and the Government of Brazil to eliminate all benefits determined by Commerce to constitute subsidies on exports of pellets to the United States. The suspension agreement would have eliminated imposition of any countervailing duty, as well as any further action on the matter by Commerce or the ITC.

The countervailing duty investigation was unexpectedly reopened in mid-June at the request of CVRD. On December 18, the Government of Brazil formally notified Commerce of CVRD's withdrawal from the suspension agreement. The trade case was still active at the end of 1985.

## WORLD REVIEW

World production, trade, and consumption of iron ore increased slightly in 1985, compared with the levels of 1984, as output of iron and steel stabilized in most industrialized countries and in many developing countries as well after recovering from the 1982-83 recession. World trade was estimated at 360 million long tons, of which about 85% was oceanborne. Brazil was the leading exporter, followed by Australia, with each country shipping more than 87 million tons to world markets. Japan remained the principal importer, receiving 123 million tons in 1985, while countries of the EC imported about 118 million tons.

World production of pellets was estimated at 195 million tons, about 80% of installed capacity. Several pelletizing plants were reactivated because of declining fuel costs, while most others operated close to rated capacity owing to relatively improved demand from their principal markets. A new plant was completed in Bahrain, while others were under construction in India, the Republic of South Africa, and Turkey.

World output of DRI was estimated at slightly more than 10.8 million tons, about 51% of installed capacity, as low prices for ferrous scrap continued to limit production. About 51% of the total output was produced in Mexico, Venezuela, and other countries in Latin America. New direct-reduction (DR) plants were completed in Iran, Malaysia, the Republic of South Africa, and the

U.S.S.R., while others were under construction in at least seven countries.

Most negotiations of 1985 iron ore prices under Japanese and Western European contracts with foreign producers were completed by mid-August. Overall, compared with 1984 prices, prices for lump ore and fines increased 1.5% to 6%, while prices for pellets declined slightly. Japanese prices for fines from Canada, Chile, and Peru were unchanged, while prices for Indian ores were increased despite an earlier agreement to maintain them at 1984 levels. Price declines for Peruvian pellets and for South African ores destined for Japan ranged from 4% to nearly 7%, possibly because of the relatively high alkali content of the ores. The price increases for lump ore and fines, which together made up about 85% of Japanese imports, were similar to those negotiated between producers and Western European buyers earlier in the year. Negotiations in both consuming regions were protracted, as buyers were determined to hold prices down because of the strength of the U.S. dollar (in which prices are quoted), and producers held out for increased prices because of stronger demand, especially for lump ore and pellets. On an f.o.b. (shipping port) basis, most 1985 prices apparently ranged from about $15 to $17.50 per long dry ton (ldt) for fines, $16 to $20.50 per ldt for lump, and $22.50 to $25.50 per ldt for pellets. Delivered prices (at receiving port) were about $2 to $9 higher, depending on ocean freight costs. The Japanese contract prices listed below are f.o.b., in U.S. cents per dry ltu of iron unless otherwise indicated:

| Country and producer | Ore type | Prices | |
|---|---|---|---|
| | | FY 1984 | FY 1985 |
| Australia: | | | |
| Hamersley Iron Pty. Ltd. and Mount Newman Mining Co. Pty. Ltd. | Lump ore | 30.87 | 31.55 |
| Do | Fines | 26.67 | 27.05 |
| Cliffs Robe River Iron Associates | do | 23.67 | 24.05 |
| Savage River Mines Ltd | Pellets | 38.30 | 37.10 |
| Brazil: | | | |
| Cia. Vale do Rio Doce and Minerações Brasileiras Reunidas S.A. | Lump ore | 24.27 | 24.65 |
| Minerações Brasileiras Reunidas S.A | Fines | 24.94 | 25.33 |
| Samarco Mineração S.A | Pellet fines | 20.25 | 20.46 |
| Cia. Nipo-Brasileira de Pelotização (Nibrasco). | Pellets | 37.31 | 36.25 |
| Canada: Iron Ore Company of Canada (Carol Lake). | Fines | 23.37 | 23.37 |
| Chile: Cía. Minera del Pacífico S.A. (El Algarrobo). | Pellets | 38.80 | 37.60 |
| India: | | | |
| Minerals and Metals Trading Corp. (Bailadila). | Lump ore | 30.06 | 30.73 |
| Do | Fines | 25.86 | 26.23 |
| Liberia: LAMCO Joint Venture Operating Co | do | 22.20 | 23.30 |
| Peru: Empresa Minera del Hierro del Perú S.A. | Pellets | 30.80 | 29.50 |
| South Africa, Republic of: | | | |
| South African Iron and Steel Industrial Corp. Ltd. | Lump ore | [1]27.19 | [1]25.86 |
| Do | Fines | [1]23.89 | [1]22.26 |

[1]Price per dry metric ton unit.

Source: TEX Report (Tokyo), v. 17, Nos. 4009 and 4013, Aug. 2, and 9, 1985.

**Australia.**—Shipments of iron ore by Australian producers in 1985 totaled about 94 million tons, including 87 million tons for export and 7 million tons for domestic consumption. Actual exports totaled about 84 million tons, of which 82% was destined for Japan and other Asian countries and 18% was destined for Western Europe. Exports consisted of about 58% sinter fines, 39% lump ore, and 3% pellets. Shipments by individual producers follow, in million tons: Hamersley Iron Pty. Ltd., 38.6; Mount Newman Mining Co. Pty. Ltd., 28.5; Cliffs Robe River Iron Associates, 14.9; The Broken Hill Pty. Co. Ltd. (BHP), 5.2; Goldsworthy Mining Ltd., 4.5; and Savage River Mines Ltd., 2.6.

In June, Mount Isa Mines Holdings Ltd. completed the sale of its 20% interest in Goldsworthy Mining to Renison Gold Fields Ltd., one of its partners in the venture. As a result of this sale, ownership will be shared between Renison Gold Fields (58.3%) and BHP (41.7%). Goldsworthy Mining operates the Shay Gap and Sunrise Hill iron mines in the Pilbara region of Western Australia. The company recently installed a pilot beneficiation plant at its Mount Goldsworthy Mine, where mining was suspended in December 1982, to test the feasibility of upgrading 100 million tons of marginal reserves containing 58.0% to 60.7% iron that occur at five deposits in the area.

In December, BHP Minerals Ltd. acquired the 25% and 30% interests in the Mount Newman Joint Venture held, respectively, by AMAX Iron Ore Corp. and Pilbara Iron Ltd. The two acquisitions raised BHP's equity in the venture from 30% to 85%. The joint venture mines the 1.1-billion-ton Mount Whaleback ore body and the 153-million-ton Marra Mamba No. 29 ore body in the southeastern corner of Western Australia's Hamersley Iron Province. AMAX will no longer act as sales agent outside Australia for Mount Newman and has agreed to transfer this function to BHP as well, effectively withdrawing from the world iron ore market. Earlier in the year, BHP shut down its mine on Cockatoo Island in Yampi Sound, northeast of the Pilbara coast. The mine, which shipped 31 million tons of ore during its 33-year life, will continue to ship stockpiled material over the next 2 years.

**Bahrain.**—The pelletizing plant of Arab Iron & Steel Co. (AISCO) shipped about 700,000 tons of pellets during its first year of operation. The Bahraini facility is the world's first merchant pelletizing plant to be based wholly on imported iron ore. The $310 million plant, commissioned in November 1984, has a production capacity of 4 million tons of pellets per year and uses a grate-kiln pelletizing system fueled by natural gas from local oilfields. It is a joint venture of Arab organizations and the public sectors of Bahrain, Kuwait, Saudi Arabia, and the United Arab Emirates, and was built to produce pellets for DR plants along the Persian Gulf and in Southeast Asia. Difficulty in finding buyers for AISCO's product has forced management to adopt a 30-day-up and 30-day-down production schedule. Saudi Iron & Steel Co. has reportedly placed an order for 60,000 tons to be delivered in 1986 to its DR plant at Jubail. However, the ongoing war between Iran and Iraq has completely disrupted markets in the rest of the region, forcing AISCO to seek out customers in the EC, Turkey, and northern Africa.

**Brazil.**—Shipments of iron ore for export and domestic consumption rose to record-high levels for the second year in a row. Exports totaled about 91 million tons, 4% more than those of 1984, while net shipments for domestic consumption increased more than 55% to 34 million tons. Exports included about 45 million tons to Europe and 27 million tons to Japan. Total shipments of pellets were estimated at about 20 million tons.

CVRD produced 73.7 million tons of iron ore products and exported 50.6 million tons. CVRD also exported 18.9 million tons for other companies, including about 8.7 million tons of pellets for its joint ventures at Tubarão with Japanese, Italian, and Spanish companies, 7.4 million tons of ore products for Ferteco Mineração S.A., and 2.8 million tons for S.A. Mineração da Trindade (SAMITRI). Most of CVRD's production came from the Caue and Conceição Mines near Itabira. Minas da Serra Geral S.A., owned 51% by CVRD, sold about 10.3 million tons of ore from the Capanema Mine for beneficiation at the Timbopeba plant and shipment to the Tubarão steelworks.

CVRD's huge $5 billion Carajás project in the State of Pará was more than 80% completed by yearend.[3] The N4E Mine began shipping trial amounts of ore in midyear, and was scheduled to reach full production capacity of 35 million tons per year, averaging 66.13% iron, in July 1987. About 12 million tons of overburden already had been removed at the N4E project site. The $1.3 billion, 550-mile-long railroad between the mine and São Luis on the coast of Maranhão was inaugurated on February 28, 1985, with the first cargoes of iron and manganese ores being transshipped to the old port of Itaqui. A total of 539,000 tons of iron ore was exported through Itaqui during the year. The new marine terminal at nearby Ponta da Madeira was almost completed and was scheduled to open in January 1986. The terminal will be able to accommodate vessels with a carrying capacity of 280,000 tons.

MBR, Brazil's second largest producer, shipped 15.1 million tons of ore in 1985, including 13.1 million tons for export. Most of the ore was produced at the Aguas Claras Mine, southeast of Belo Horizonte in the Minas Gerais Iron Ore Quadrangle. Empreendimentos Brasileiros de Mineração S.A. owns 51% of MBR, while Hanna has an indirect interest of 34% through the St. John d'el Rey Mining Co. PLC. Another 5% is indirectly held by Bethlehem Steel.

Ore shipments by other producers, in million tons, follow: Ferteco (sales), 8.6; SAMITRI, 8.9; Samarco Mineração S.A., 6.7; Cia. Siderúrgica Nacional, 4.8 (estimated); William H. Mueller S.A., 1.1; and Empresa de Mineração Esperanca S.A., 0.2.

**Canada.**—Shipments of iron ore products totaled 40.2 million tons, compared with 40.7 million tons in 1984. Exports totaled about 24.7 million tons, of which 57% was destined for EC countries and 29% was destined for the United States. Domestic consumption was estimated at 14.8 million tons.

Shipments of ore by individual producers, in million tons, follow: Iron Ore Co. of Canada, 14.9 including 8.3 of pellets, 4.8 of concentrates, and 1.8 of direct-shipping ore; Quebec Cartier Mining Co., 15.6, including 8.9 of concentrates and 6.7 of pellets; Pickands Mather, 6.0 of pellets including 5.5 from Wabush Mines; Cliffs of Canada Ltd. (for Dofasco Inc.), 2.1 of pellets from the Adams and Sherman Mines; and Inco Ltd., 0.09 of pellets from stockpile. The Algoma Steel Corp. Ltd. shipped 1.4 million tons of superfluxed sinter from Wawa, Ontario, to its steelworks at Sault Ste. Marie. Feed to the sinter plant included 1.6 million tons of siderite ore produced at the MacLeod underground mine.

Stelco Inc. took steps to permanently close its Griffith Mine and pelletizing plant near Red Lake, Ontario. The mine produced only 475,000 tons of pellets, 50% of capacity in 1985 and is operated for Stelco by Pickands Mather.

**China.**—China was expanding the iron and steel complexes at Panzhihua near Dukou in Sichuan Province, Maanshan in Anhui Province, and Handan in Hebei Province as part of its seventh 5-year plan (1986-90). Construction of new steelmaking facilities and modernization of existing plants was in progress at each of three sites and was expected to be completed by 1995. Panzhihua and Maanshan both have their own titaniferous magnetite mines and are major producers of vanadiferous slags that average 17% vanadium pentoxide. The Panzhihua blast furnace operations also produce a titaniferous slag containing 12% to 14% titanium dioxide. This second type of slag is used as feed for the Zunyi titanium sponge plant in Guizhou.

The Panzhihua complex would have an annual production capacity of 2.8 million tons of pig iron when the new 1,350-cubic-meter blast furnace is completed. The present plant reportedly was producing 1.5 million tons of pig iron annually with its three existing blast furnaces. The project would include the construction of a new sinter plant, a hot rolling mill, and two coke oven batteries. According to Xinhua, an official Chinese news agency, the Panzhihua deposit contains more than 10 billion tons of iron ore and accounts for 93% of the country's titanium reserves and 87% of its vanadium reserves. An earlier report stated that the iron mine had only 1.03 billion tons of ore grading 33.2% iron, 11.6% titanium dioxide, and 0.3% vanadium pentoxide. The 10-year expansion program was expected to raise raw steel production capacity from 1.75 million metric tons per year to 2.5 million tons per year, making Panzhihua the largest iron and steel center in southwestern China.

A new 2,500-cubic-meter blast furnace and a new sinter plant would also be installed at Maanshan. Existing plans called for the 30% to 50% iron ore at Maanshan to be blended with Australian ore as feed for the new sinter plant. The existing open hearth furnaces were to be replaced by either oxygen converters or electric arc furnaces. One of the first improvements would be the construction of a new oxygen plant for the steel mill. Maanshan has an annual raw steel capacity of 1 million tons and employs 60,000 workers.

**Guinea.**—A recently completed, $500,000 study to examine the most economical means of developing the Mifergui-Nimba Co. iron deposit found that the deposit would require a $267 million investment for a 10-million-ton-per-year operation. An 11-mile rail line would be built to haul the ore from its location on the Liberian border to the existing railway of the LAMCO Joint Venture Operating Co. (LJV) inside Liberia. The Guinean ore could then be processed along with LJV's ore and shipped an additional 167 miles to the Liberian Port of Buchanan for export. The port facilities can currently handle vessels with a carrying capacity of 80,000 tons. The results of the study were being reviewed by both the Government of Guinea and the Mifergui-Nimba shareholders. The study was funded by the International Bank for Reconstruction and Development (World Bank) and carried out by Granges International Mining and U.S. Steel. According to the World Bank, a follow-on study was being undertaken to assess the economic viability of the project and the marketability of the ore.

Development of the deposit could extend the life of LJV's Nimba Mine by permitting the company to mix its diminishing, lower grade Liberian ore with the richer Guinean ore. Furthermore, Nigeria, an investor in Mifergui-Nimba, could benefit from access to West African ore that might be more economic because of lower ocean shipping costs.

**Hungary.**—The Ministry of Industry announced that the Rudabanya Mine, near Miskolc in Borsod-Abauj-Zemplen County, would be closed on January 22, 1986. Production at the country's only active iron mine declined from 434,000 tons in 1983 to 306,000 tons in 1985. The grade of the Rudabanya ore traditionally has been low and reportedly has fallen to a point where beneficiation is no longer economical. The mine has been able to satisfy only a minor part of Hungarian demand.

**India.**—Production, exports, and consumption of iron ore increased in 1985 compared with 1984 levels. Exports totaled 28.4 million tons and domestic consumption was estimated at 13.5 million tons. Exports included 19.2 million tons to Japan, 2.9 million tons to the Republic of Korea, and 2.5 million tons to Romania. Shipments from Goa totaled 13.7 million tons, and shipments from east coast ports by the National Mineral Development Corp. totaled 7.5 million tons.

The 3-million-ton pelletizing plant of Kudremukh Iron Ore Co. Ltd. (KIOC) at the Port of Mangalore was completed in June and was undergoing testing. The plant will receive concentrates through a 42-mile pipeline from the Kudremukh Mines in the Western Ghats. Commissioning was delayed by a miners' strike that lasted from September 3 to November 2. The opening ceremony has been rescheduled for April 1, 1986. The first pellets are to be shipped to Malaysia for feed in DR plants. KIOC shipped about 1.6 million tons of pellet feed in 1985, most of which went to Japan. The company has signed a contract with AISCO to supply 6.5 to 8.3 million tons of concentrates to Bahrain between April 1985 and March 1989.

Minerals and Metals Trading Corp. of India was seeking financial assistance for a $90 million port expansion and channel dredging project at Paradip. The port would be able to accommodate ships up to 200,000 deadweight tons, compared with the existing limit of 60,000 tons. The project would also increase iron ore handling capacity from the present 2 million tons per year to 6 million tons per year.

**Japan.**—Imports of iron ore decreased to 122.5 million tons from 123.4 million tons in 1984. Production of pig iron, in contrast, rose slightly from 79.1 to 79.3 million tons. The principal suppliers continued to be Australia, Brazil, and India. Consumption of ore was estimated at 130 million tons.

**Liberia.**—Exports of iron ore products totaled 16.1 million tons, of which 81% was destined for the EC and 13% was destined for the United States. Exports included 11.9 million tons of sinter fines, 3.2 million tons of pellets, and 1.0 million tons of lump ore. All of the pellets and slightly more than one-third of the sinter fines were shipped by Bong Mining Co.

Shipments by LJV totaled 8.4 million tons, about 7% less than in 1984. The company planned to resume production near Tokadeh and was seeking loans for the purchase of mining equipment. The main ore body at the Nimba Mine could be exhausted as early as 1989. However, the western concession areas, which include the Tokadeh, Gangra, and Yuelliton ore bodies, have a total reserve of 400 million tons of crude ore, averaging 50.8% iron. Bethlehem Steel sold its 25% interest in LJV to the Government of Liberia in January 1984 and agreed to purchase 2 million tons of ore annually for a period of 3 years.

The National Iron Ore Co. (NIOC) produced only about 211,000 tons of ore products in 1985. The company has had increasing difficulty finding buyers for its ore in recent years. The financial condition of NIOC has continued to deteriorate despite a loan from the World Bank. On April 1, 1985, NIOC closed its mine near the border with Sierra Leone and began winding down operations. Only limited amounts of siliceous fines have been produced since April.

**Malaysia.**—The DR plant of Sabah Gas Industries Sdn. Bhd. (SGI) on Labuan Island was completed in early 1984, but did not go into production until the end of the year because of technical problems in the briquetting plant. Since then, SGI has shipped a total of 30,000 tons of hot-briquetted iron to 30 Indian minimills for evaluation. The SGI operation is somewhat unique because it is the first plant to use a modified version of the Midrex process that permits the hot DRI to be discharged directly into the briquetting machines. At Trengganu, the new DR plant of Perwaja Trengganu Sdn. Bhd. reached full-scale production in March. The company initially was using Brazilian and

Swedish pellets along with high-grade Brazilian lump ore as feed. Designed production capacity of each plant is about 650,000 tons of DRI per year.

**Mauritania.**—Exports of iron ore totaled 9.2 million tons, about 2% less than those of 1984. As in the past 2 years, more than 90% of shipments was destined for EC countries.

The first stage of the Guelbs project was inaugurated in July 1984 and scheduled to reach a production rate of 6 million tons per year by the end of 1987. Mechanical difficulties with a conveyor belt and other ore handling equipment at the mine temporarily delayed the first shipments. Magnetic concentrates were being produced from crude ore mined at El Rhein, about 15 miles north of the Kedia d'Idjil hematite mines. Owing to scarcity of water, the ore was being beneficiated in the dry state, using semiautogenous mills and low-intensity magnetic separators.

**New Zealand.**—New Zealand Steel Mining Ltd. produced 1.9 million dry tons of titaniferous magnetite concentrates at its beach sand operations on the North Island. Shipments of the concentrates, loosely referred to as "iron sand," included exports of about 1.8 million tons to Japan and 201,000 tons to the Woolf Fisher steelworks of the parent company in South Auckland. New Zealand is currently the sole supplier of iron sand to the Japanese steel industry, where it is added to the blast furnace feed to extend the life of the refractories. Three specially equipped Japanese carriers—the *Taharoa Maru* (126,604 deadweight tons), the *Slurry Express* (122,042 deadweight tons), and the *Taharoa Venture* (124,589 deadweight tons)—haul the iron sand to Japan.

**Peru.**—Exports of iron ore by Empresa Minera del Hierro del Perú in 1985 totaled 5.2 million dry tons, of which 44% consisted of sinter fines, 37% consisted of pellets, and the remainder was pellet feed. About 2.0 million tons of products was shipped to the Republic of Korea, and 1.4 million tons was shipped to Japan. All of the material passed through the Port of San Nicolás. An additional 345,000 tons of mostly pellets went to the Chimbote steel mill operated by Empresa Siderúrgica del Perú.

**South Africa, Republic of.**—Production and exports of iron declined slightly from 1984 levels. Production totaled 24.0 million tons, compared with 24.3 million tons in 1984. Exports totaled 10.0 million tons, mostly to Japan and the EC. Domestic sales were 10.4 million tons, as production of pig iron increased 21% and output of DRI jumped to 405,000 tons. All four of the new Lurgi DR rotary kilns at the Vanderbijlpark steelworks of South African Iron and Steel Industrial Corp. Ltd. (Iscor) were in operation at the beginning of 1985. The units have a total design capacity of 709,000 tons of DRI.

Iscor was supplied with 8.4 million tons of ore products from the Sishen Mine and 2.3 million tons from the Thabazimbi Mine. An additional 8.71 million tons was exported from the Sishen Mine through Saldanha Bay. Increased freight charges on the railway from Sishen to Saldanha Bay, reduced ore prices, and nonrenewal of several sales contracts in Western Europe had made exports of ore products increasingly unprofitable. However, the decline of the rand against the dollar and the adoption of certain rationalization measures by Iscor improved the company's position. On September 7, the company exported its 100 millionth ton of ore from Saldanha Bay. At the Sishen Mine, the South Plant, which accounts for one-third of the mine's production capacity of 27 million tons per year, was reopened in the second quarter at a reduced rate. At midyear, the North Plant was operating at full capacity. The life of the Thabazimbi Mine has been extended by the discovery of a minable ore body west of the Donkerpoort open pit. At Iscor's Pretoria Works, workers began constructing the foundations for a 300,000-ton-per-year ironmaking plant. The new plant will utilize the KR—Kohle reduktion (coal reduction)—process developed by Korf Engineering GmbH in Austria and the Federal Republic of Germany.

**Spain.**—Production of iron ore products in 1985 included a record high 3.7 million tons by Cía. Andaluza de Minas S.A. (CAM); 1.3 million tons by the Agruminsa subsidiary of Altos Hornos de Vizcaya S.A. (AHV); and 1.2 million tons by Cía. Minera de Sierra Menera S.A. CAM's production, consisting of sinter fines, came from the Marquesado Mine at Alquife. Agruminsa's production included siderite concentrates from ore mined underground at Bodovalle as well as oxide ores from four other locations in Spain. In September, Agruminsa closed its Gallarta Mine near Bodovalle for at least 6 months to reduce stocks of sinter feed from 1.1 million tons to 400,000 tons. The Gallarta ores traditionally have been shipped to AHV's sinter plant at Sestao. However, renovation of the No. 2A blast furnace at the Sestao steelworks temporarily reduced demand for the mine's product.

Spanish exports of iron ore totaled 2.0 million tons, of which CAM shipped 1.8 million tons from the Port of Almeria; most of the remainder was shipped from Sagunto by the Sierra Menera company. Imports totaled 4.9 million tons, of which 60% came from Brazil.

**Sweden.**—Production and exports of iron ore products increased by 28% and 5%, respectively, from 1984 levels. Exports totaled 18.4 million tons including 5.5 million tons of pellets. About 3.8 million tons was shipped for domestic consumption. Stocks of iron ore were reduced by 0.9 million tons, to 3.6 million tons at yearend.

Luossavaara-Kiirunavaara AB (LKAB) produced 17.6 million tons including 8.6 million tons of pellets. Of the company's output, 52% was produced at Kiruna, 34% was produced at Malmberget, and the rest was produced at the Svappavaara pelletizing plant, which resumed production in November 1984. Shipments totaled 18.6 million tons, mostly for export. LKAB increased the capacity of its pelletizing plant at Kiruna to 4 million tons per year, and a steel-belt pelletizing plant began production at Malmberget in late 1985.

Svenskt Stål AB produced 1.9 million tons of concentrates at Grangesberg, including 1 million tons of granulated sinter feed, and produced 500,000 tons of ore products at the Dannemora Mine. These production levels were almost identical to those of 1984. Combined shipments totaled 3.1 million tons including 1.9 million tons for export.

**U.S.S.R.**—Soviet exports were estimated at 45.0 million tons. According to the Association of Iron Ore Exporting Countries, exports in 1984 totaled 45.2 million tons, of which 10.5 million tons were pellets and 34.7 million tons were lump ore and other products. The material in the latter category included 10.9 million tons to Poland, 9.4 million tons to Czechoslovakia, 4.3 million tons to Romania, and 3.9 million tons to Hungary.

On June 16, the Soviet Premier and the President of Finland formally inaugurated the third stage of the Kostamush project near Lake Kujto in the Karelia A.S.S.R. The mining complex, begun in late 1977, is designed to produce 9 million tons of nonfluxed pellets per year from 24 million tons of ferruginous quartzite ores. The project began production in 1982 when the first of three pelletizing plants, each with a capacity of 2.9 million tons per year of pellets, was completed. All three plants were in operation at mid-1985. The bulk of the pellets reportedly were being railed to the new, 5,600-cubic-meter blast furnace of the Cherepovets Iron and Steel Works, while most of the remainder was being exported to the Raahe Steel Works of Rautaruukki Oy in Finland.

The main processing facilities of Kostamush were designed by the Mekhanobr Institute of Leningrad, with supervision from the Giproruda Planning Institute of the Soviet Ministry of Ferrous Metallurgy. Much of the construction and civil engineering work was carried out by a consortium of 15 Finnish companies led by Finn-Stroi Ltd. The ore body, which was discovered in 1945, contains some 2 billion tons of magnetite ore averaging 31% iron. Beneficiation is complicated by the presence of 0.1% to 3% pyrrhotite and other sulfides in the ore. The finished pellets contain 65.6% iron and less than 0.05% sulfur.[4]

In the fall, the second of four Midrex DR modules was commissioned at the Stary Oskol Iron and Steel Works near Kursk. The third module was already under construction and was expected to be operational by mid-1987. When completed, the DR complex, which is operated by Oskolskiy Electro-Metallurgicheskiy Kombinat (OEMK) will have a capacity of 1.7 million tons of DRI. OEMK produced 420,000 tons of DRI in 1985, primarily with the No. 1 module, and now has an existing capacity of 830,000 tons. OEMK also has its own pelletizing plant, which receives concentrates through a 16-mile-long slurry pipeline from the Gubkin Mine and beneficiation plant in the Kursk Magnetic Anomaly. The Gubkin Mine produced 40 million tons of Lake Superior-type ore, averaging 33% iron, in 1984 and has reserves in excess of 35 billion tons.

**Venezuela.**—Shipments of iron ore products by the state-owned CVG Ferrominera Orinoco C.A. totaled 14.5 million tons and included about 8.9 million tons for export. Domestic consumption was estimated at 4.8 million tons.

Ferrominera began production in September at its Cerro San Isidro Mine near Cerro Bolivar. The new mine is linked by an 11-mile railway to the main line between

Cerro Bolivar and the docks at Puerto Ordaz. Ore from the open pit operation, which had a capacity of 5 million tons per year, was scheduled to replace about 45% of the production from the Cerro Bolivar Mine in 1986. To accomplish this, San Isidro's output would be raised to 9 million tons per year. Shipments for the first year totaled about 1.4 million tons. A primary objective of the $20 million development was to improve the average grade of ore marketed by the company, creating savings in beneficiating costs. San Isidro ore contains about 0.06% phosphorus, compared with 0.11% at Cerro Bolivar, and the iron content of San Isidro ore is reportedly higher than that at Cerro Bolivar. El Pao, Ferrominera's third mine, shipped about 3 million tons in 1985, but its reserves could be exhausted as early as 1991.

Production of DRI in 1985 was 2.6 million tons, of which about 52% was produced by the Midrex process, 38% was produced by the HYL process, and the rest was produced by Fior de Venezuela S.A. Under contract with Ferrominera, Midrex Corp. was studying the feasibility of modifying the high-iron briquet (HIB) reduction plant at Puerto Ordaz to use the Midrex process. The HIB plant, closed since 1982, would primarily use screened lump ore from San Isidro as feed material. The plant belongs to Minerales Ordaz C.A., a subsidiary of Ferrominera.

**Yugoslavia.**—Rudarsko Metalurski Kombinat Zenica commissioned its $12 million Omarska Mine on November 1. The mine, near Prijedor in Bosnia-Hercegovina, had been under development for 10 years and will permit Yugoslavia to reduce drastically its dependency on imported ore. In recent years, the country has imported from 1.0 to 1.5 million tons of ore and concentrate per year, mainly from Brazil, India, Peru, and the U.S.S.R. Omarska has an initial production goal of only 400,000 tons of concentrates per year containing 53% iron, but is designed to produce 1.7 million tons per year, which will more than compensate for the exhaustion of several smaller operations.

## TECHNOLOGY

Intense competition in iron ore and steel markets and the need to reduce costs continued to stimulate technological improvements in iron ore production and use.

In December, Michigan Technological University (MTU) received a $5.75 million appropriation from the State of Michigan for construction of a demonstration plant that would test a novel ironmaking operation.[8] The ironmaking operation would integrate two patented technologies. The MTU-PELLETECH or cold-bond agglomeration process first would be used to form pellets from a mixture of iron ore fines, carbon fines, and burnt lime. The carbon-bearing pellets would then be reduced in a hot blast cupola to produce molten iron, using a process developed by Pellet Technology Corp. (PTC). PTC, a partnership between MTU and a Pennsylvania entrepreneur, would be responsible for operating both the 80,000-ton-per-year demonstration MTU-PELLETECH pelletizing plant and the 1-1/2-ton-per-hour PTC hot metal pilot plant. Construction of the new facility, which would cost $16 to $20 million in State and private funds, was scheduled to begin in July 1986 at Eagle Mills on the Marquette Range.

The cold-bond agglomeration process has been under development at MTU since the 1960's. The carbon-bearing pellets made by this process can be used either in a blast furnace to produce conventional pig iron, or in a cupola furnace to produce a variety of reduced iron products. The PTC hot metal process should cut pellet reduction time and furnace fuel costs as well as eliminate the enormous costs of building and maintaining a blast furnace. Relatively small amounts of hot metal could be produced profitably in a scaled-down cupola, an impossibility with a conventional blast furnace. The pellets can be used successfully in the cupola because the carbon fines and burnt lime incorporated into the pellet accelerate the rate of reduction. The carbon fines act as a reducing agent, while the burnt lime serves as a bonding agent. Hot metal costs are reported to be as low as $100 to $110 per ton in the PTC process compared with the current $160 to $170 per ton for the blast furnace. The MTU pellets can also be fed into rotary kilns to produce DRI. A large variety of iron oxides of varying quality can be utilized for pellet feed, including iron ore concentrates, steel dust from basic oxygen furnaces, mill scale, and blast furnace sludge. Carbon sources can include coke breeze, anthracite, and coal char. Pellet production costs were expected to be less than those for conventional processes because the pellets are indurated at a lower temperature in less time than in existing pelletizing facilities (i.e., a PTC autoclave would be operated at approximately 390° F compared with 2,400° F for a conventional kiln). Because of the lower temperature of the autoclaving process, the MTU pellets are in the form of magnetite, instead of hematite. This phase phenomenon creates a pellet that has more iron per unit volume and that requires less energy to reduce.

Oxide Recycle Corp. has been designated PTC's exclusive licensee for the North American iron and steel industry. In late 1985, Oxide Recycle began building a PTC hot metal facility in Gary, IN, that would produce iron from steel-plant wastes. This second facility, scheduled for completion by the end of 1987, will have a design capacity of 1.5 million tons per year of molten iron. Production costs would be partially offset by earnings from the waste collection part of the operation. Disposal charges for mill scale, dust, and slag have been running as high as $150 per ton of waste.

The State of Minnesota, U.S. Steel, and Korf Engineering have applied for nearly $100 million in Federal grants and loans to demonstrate new ironmaking technology that could make domestic steel more competitive with imports. The funds would be used to finance a plant in northern Minnesota that would produce 360,000 tons of iron per year with less pollution and possibly at lower cost than iron produced by the conventional coke oven and blast furnace process. The plant would be the first in North America to produce iron commercially through the method developed by Korf Engineering. The KR process eliminates the blast furnace in pig iron production by using coal instead of coke, thus avoiding the costs and environmental problems of coke production. The reactions in the process are similar to those in the conventional blast furnace, but they take place in two separate chambers. One contains a fluidized bed where coal is gasified and prereduced iron is melted. The second chamber is a vertical shaft furnace where ore is reduced by gas from the fluidized bed. Korf Engineering, U.S. Steel, and the State of Minnesota submitted the $94.8 million proposal in February to the U.S. Department of Energy.

Weirton Steel Corp. has also applied to Energy for a $65 million grant to cover about one-half the cost of building and operating, for 1 year, a similar KR plant. Funds for the other half of the project would be provided by the State of West Virginia and West Virginia coal producers.

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[1] Physical scientist, Division of Ferrous Metals. The author was assisted in preparation of this chapter by F. L. Klinger, physical scientist, Division of Ferrous Metals (retired), and William I. Spinrad, Jr., physical scientist, Division of Ferrous Metals (now with the National Park Service, Atlanta, GA).

[2] Unless otherwise specified, the unit of weight used in this chapter is the long ton of 2,240 pounds.

[3] Engineering and Mining Journal. Carajas Iron Ore. V. 186, No. 11, Nov. 1985, pp. 34-42.

[4] Mining Magazine. The Kostomuksha Project. V. 153, No. 3, Sept. 1985, pp. 193-197.

[5] Skillings' Mining Review. Pellet Technology Corp. To Demonstrate New Ironmaking Process at Eagle Mills, MI. V. 75, No. 15, Apr. 12, 1986, pp. 4-6.

### Table 2.—Employment at iron ore mines and beneficiating plants, quantity and tenor of ore produced, and average output per worker hour in the United States in 1985, by district and State

| District and State | Average number of employees | Worker hours (thousands) | Production (thousand long tons) | | | Iron content (natural) percent | Average per worker hour (long tons) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Crude ore | Usable ore | Iron contained (in usable ore) | | Crude ore | Usable ore | Iron contained |
| Lake Superior: | | | | | | | | | |
| Michigan | 2,083 | 3,427 | 38,656 | 12,479 | 8,052 | 64.5 | 11.28 | 3.64 | 2.35 |
| Minnesota | 5,780 | 10,020 | 108,394 | 34,910 | 22,411 | 64.2 | 10.82 | 3.48 | 2.24 |
| Total or average[1] | 7,863 | 13,447 | 147,050 | 47,388 | 30,463 | 64.3 | 10.94 | 3.52 | 2.27 |
| Other States[2] | 315 | 595 | 2,162 | 1,363 | 834 | 61.2 | 3.63 | 2.29 | 1.40 |
| Grand total or average[1] | 8,178 | 14,042 | 149,212 | 48,751 | 31,296 | 64.2 | 10.63 | 3.47 | 2.23 |

[1] Data may not add to totals shown because of independent rounding.

[2] Includes California, Colorado, Missouri, Montana, Nevada, and Texas.

## Table 3.—Crude iron ore[1] mined in the United States in 1985, by district, State, and mining method

(Thousand long tons and exclusive of ore containing 5% or more manganese)

| District and State | Number of mines | Open pit | Under-ground | Total quantity |
|---|---|---|---|---|
| Lake Superior: | | | | |
| Michigan | 2 | 38,656 | -- | 38,656 |
| Minnesota | 11 | 108,394 | -- | 108,394 |
| Total | 13 | 147,050 | -- | 147,050 |
| Other States: | | | | |
| Missouri | 1 | -- | 1,675 | 1,675 |
| Other[2] | 6 | 486 | -- | 486 |
| Total | 7 | 486 | 1,675 | [3]2,162 |
| Grand total | 20 | 147,536 | 1,675 | [3]149,212 |

[1] Excludes byproduct ore.
[2] Includes California, Colorado, Montana, Nevada, and Texas.
[3] Data do not add to total shown because of independent rounding.

## Table 4.—Usable iron ore produced in the United States in 1985, by district, State, and type of product

(Thousand long tons and exclusive of ore containing 5% or more manganese)

| District and State | Direct-shipping ore | Concen-trates | Agglomer-ates | Total quantity[1] |
|---|---|---|---|---|
| Lake Superior: | | | | |
| Michigan | -- | -- | 12,479 | 12,479 |
| Minnesota | -- | 1,462 | 33,448 | 34,910 |
| Total[1] | -- | 1,462 | 45,927 | 47,388 |
| Other States: | | | | |
| Missouri | -- | 56 | 1,044 | 1,099 |
| Other[2] | 58 | 206 | -- | 263 |
| Total[1] | 58 | 261 | 1,044 | 1,363 |
| Grand total[1] | 58 | 1,723 | 46,970 | 48,751 |

[1] Data may not add to totals shown because of independent rounding.
[2] Includes California, Colorado, Montana, Nevada, and Texas.

## Table 5.—Shipments of usable iron ore[1] from mines in the United States in 1985

(Exclusive of ore containing 5% or more manganese)

| District and State | Gross weight of ore shipped (thousand long tons) | | | | Average iron content (natural) percent | Total value (thousand dollars) |
|---|---|---|---|---|---|---|
| | Direct-shipping ore | Concentrates | Agglomerates | Total quantity | | |
| Lake Superior: | | | | | | |
| Michigan | -- | -- | 12,629 | 12,629 | 64.2 | W |
| Minnesota | -- | 1,458 | 33,519 | 34,977 | 63.7 | 1,430,353 |
| Total reportable | -- | 1,458 | 46,148 | 47,606 | 63.9 | 1,430,353 |
| Other States: | | | | | | |
| Missouri | -- | 56 | 1,054 | 1,110 | 65.9 | W |
| Other[2] | 60 | 634 | ([3]) | 694 | 55.1 | 12,997 |
| Total reportable | 60 | 690 | 1,054 | 1,804 | 61.8 | 12,997 |
| Total withheld | -- | -- | -- | -- | -- | 633,381 |
| Grand total[4] | 60 | 2,148 | 47,203 | 49,411 | 63.8 | 2,076,730 |

W Withheld to avoid disclosing company proprietary data; included in "Total withheld."

[1] Includes byproduct ore.

[2] Includes California, Colorado, Montana, Nevada, New Mexico, New York, and Texas.

[3] Included in concentrates.

[4] Data may not add to totals shown because of independent rounding.

## Table 6.—Usable iron ore produced in the U.S. Lake Superior district, by range

(Thousand long tons and exclusive after 1905 of ore containing 5% or more manganese)

| Year | Marquette | Menominee | Gogebic | Vermilion | Mesabi | Cuyuna | Spring Valley | Black River Falls | Total[1] |
|---|---|---|---|---|---|---|---|---|---|
| 1854-1978 | 478,058 | 325,267 | 320,334 | 103,528 | 3,182,512 | 70,336 | 8,149 | 7,221 | 4,495,401 |
| 1979 | 15,100 | 2,032 | -- | -- | 59,320 | -- | -- | 698 | 77,151 |
| 1980 | 14,450 | 1,970 | -- | -- | 45,162 | -- | -- | 699 | 62,282 |
| 1981 | 15,508 | 75 | -- | -- | 51,025 | -- | -- | 854 | 67,462 |
| 1982 | 6,874 | -- | -- | -- | 23,898 | -- | -- | 241 | 31,013 |
| 1983 | 9,339 | -- | -- | -- | 26,255 | -- | -- | -- | 35,594 |
| 1984 | 12,982 | -- | -- | -- | 36,697 | -- | -- | -- | 49,679 |
| 1985 | 12,479 | -- | -- | -- | 34,910 | -- | -- | -- | 47,388 |
| Total | 564,790 | 329,344 | 320,334 | 103,528 | 3,459,779 | 70,336 | 8,149 | 9,713 | 4,865,970 |

[1] Data may not add to totals shown because of independent rounding.

## Table 7.—Average analyses of total tonnage[1] of all grades of iron ore shipped from the U.S. Lake Superior district

| Year | Quantity (thousand long tons) | Content (percent)[2] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Iron | Phosphorus | Silica | Manganese | Alumina | Moisture |
| 1981 | 64,925 | 63.13 | 0.020 | 5.70 | 0.17 | 0.30 | 2.59 |
| 1982 | 32,173 | 63.50 | .018 | 5.40 | .13 | .31 | 2.60 |
| 1983 | 42,418 | 63.32 | .018 | 5.35 | .12 | .29 | 2.64 |
| 1984 | 48,613 | 63.48 | .018 | 5.28 | .14 | .32 | 2.66 |
| 1985 | 46,916 | 63.64 | .016 | 5.17 | .11 | .29 | 2.63 |

[1] Railroad weight—gross tons.

[2] Iron and moisture on natural basis; phosphorus, silica, manganese, and alumina on dried basis.

Source: American Iron Ore Association.

## Table 8.—U.S. consumption of iron ore and agglomerates in 1985, by State

(Thousand long tons and exclusive of ore containing 5% or more manganese)

| State | Iron ore and concentrates[1] |  | Agglomerates[2] |  | Miscellaneous[3] | Total reportable |
|---|---|---|---|---|---|---|
|  | Blast furnaces | Steel furnaces | Blast furnaces | Steel furnaces |  |  |
| Alabama, Kentucky, Texas, Utah | W | W | 7,606 | W | W | 7,606 |
| Illinois, Indiana, Michigan | W | W | 31,972 | W | W | 31,972 |
| Maryland and Pennsylvania | 995 | W | 11,885 | W | W | 12,880 |
| Ohio and West Virginia | 1,236 | W | 15,072 | W | W | 16,308 |
| Undistributed | 292 | 119 | -- | 268 | 1,129 | 1,808 |
| Total[4] | 2,524 | 119 | 66,535 | [5]268 | 1,129 | 70,575 |

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Excludes pellets or other agglomerated products.

[2] Includes approximately 42,878 units of pellets produced at U.S. mines and 7,117 units of foreign pellets and other agglomerates.

[3] Includes iron ore consumed in production of cement and iron ore shipped for use in manufacturing paint, ferrites, heavy media, cattle feed, refractory and weighting materials, and for use in lead smelting.

[4] Data may not add to totals shown because of independent rounding.

[5] Includes an estimated 220 units of ore and agglomerates used for production of direct-reduced iron for steelmaking.

## Table 9.—Iron ore consumed in production of sinter at iron and steel plants in the United States in 1985, by State

(Thousand long tons)

| State | Iron ore consumed[1] | Sinter produced |
|---|---|---|
| Indiana, Kentucky, Michigan, and Utah | 3,779 | 7,988 |
| Maryland and Pennsylvania | 3,382 | 6,333 |
| Ohio and West Virginia | 1,359 | 2,236 |
| Total | 8,520 | 16,557 |

[1] Includes domestic and foreign ores.

## Table 10.—U.S. production of iron ore agglomerates,[1] by type

(Thousand long tons)

| Type | 1984 | 1985 |
|---|---|---|
| Sinter | [2]16,926 | [3]16,557 |
| Pellets | 50,083 | 46,970 |
| Total | 67,009 | 63,527 |

[1] Production at mines and consuming plants.

[2] Includes 7,983 units of self-fluxing sinter.

[3] Includes 7,256 units of self-fluxing sinter.

## Table 11.—U.S. exports of iron ore, by country

(Thousand long tons and thousand dollars)

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value |
| Canada | 3,780 | 182,490 | 4,988 | 238,856 | 5,033 | 240,435 |
| India | (1) | 12 | (1) | 2 | -- | -- |
| Iraq | (1) | 76 | -- | -- | -- | -- |
| Mexico | (1) | 4 | (1) | 24 | (1) | 10 |
| Netherlands | -- | -- | 3 | 262 | -- | -- |
| Saudi Arabia | (1) | 34 | -- | -- | -- | -- |
| United Kingdom | (1) | 5 | (1) | 32 | -- | -- |
| Venezuela | (1) | 10 | (1) | 15 | (1) | 22 |
| Other | 1 | 113 | 1 | 66 | (1) | 87 |
| Total[2] | 3,781 | 182,744 | 4,993 | 239,257 | 5,033 | 240,557 |

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

## Table 12.—U.S. imports for consumption of iron ore, by country

(Thousand long tons and thousand dollars)

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value |
| Brazil | 1,276 | 30,192 | 2,533 | 55,132 | 2,540 | 49,322 |
| Canada | 8,832 | 339,472 | 11,190 | 413,478 | 8,557 | 325,248 |
| Chile | -- | -- | -- | -- | 164 | 2,320 |
| Liberia | 1,732 | 31,487 | 1,745 | 25,270 | 2,206 | 30,987 |
| Peru | (1) | 5 | 7 | 76 | 121 | 2,722 |
| Sweden | 68 | 1,540 | 84 | 1,659 | 65 | 1,503 |
| Venezuela | [2]1,333 | [2]42,934 | [3]1,524 | [3]31,377 | [4]2,068 | [4]39,369 |
| Other | 5 | 102 | 104 | 2,078 | 50 | 769 |
| Total | 13,246 | [5]445,731 | 17,187 | 529,065 | 15,771 | 452,240 |

[1] Less than 1/2 unit.
[2] Excludes approximately 82,000 long tons of sponge iron valued at $6,516,000, originally reported as iron ore.
[3] Excludes approximately 64,000 long tons of sponge iron valued at $5,016,000, originally reported as iron ore.
[4] Excludes approximately 214,000 long tons of sponge iron valued at $15,685,828, originally reported as iron ore.
[5] Data do not add to total shown because of independent rounding.

## Table 13.—U.S. imports for consumption of iron ore, by customs district

(Thousand long tons and thousand dollars)

| Customs district | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value |
| Baltimore | 3,062 | 63,216 | 4,668 | 133,448 | 3,678 | 71,336 |
| Buffalo | 195 | 8,362 | (1) | (1) | (1) | 5 |
| Chicago | 1,625 | 52,357 | 2,574 | 59,706 | 2,594 | 58,712 |
| Cleveland | 4,491 | 179,771 | 3,859 | 136,654 | 1,646 | 59,853 |
| Detroit | 182 | 4,480 | 393 | 12,927 | 542 | 19,107 |
| Houston | 37 | 1,169 | 133 | 2,758 | 165 | 2,541 |
| Mobile | 525 | 25,778 | 1,548 | 68,288 | 2,600 | 111,772 |
| New Orleans | 578 | 12,869 | 643 | 12,315 | 878 | 16,266 |
| Philadelphia | 2,463 | 93,963 | 3,250 | 98,777 | 3,408 | 107,029 |
| Other | 91 | 3,768 | 119 | 4,196 | 266 | 5,620 |
| Total[2] | 13,246 | 445,731 | 17,187 | 529,065 | 15,771 | 452,240 |

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

# Table 14.—Iron ore, iron ore concentrates, and iron ore agglomerates: World production, by country[1]

(Thousand long tons)

| Country[2] | Gross weight[3] | | | | | Metal content[4] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1981 | 1982 | 1983 | 1984[p] | 1985[e] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
| Albania[e][5] | 591 | [r]690 | [r]840 | [e]1,063 | 1,100 | 197 | [r]230 | [r]280 | [r]350 | 370 |
| Algeria | [r]3,426 | [r]3,831 | 3,626 | 3,606 | 3,600 | [r]1,738 | [r]1,915 | 1,813 | 1,839 | 1,840 |
| Argentina | 392 | 578 | 599 | 618 | 620 | 245 | 383 | 384 | [r][e]400 | 400 |
| Australia | 83,324 | 86,309 | 69,916 | 87,564 | 98,500 | 52,518 | 54,688 | 44,587 | 55,920 | 62,500 |
| Austria | 3,002 | 3,277 | 3,484 | 3,543 | 3,250 | 933 | 1,028 | 1,090 | 1,120 | 1,020 |
| Bolivia | 6 | 8 | 11 | -- | -- | 4 | 5 | 7 | -- | -- |
| Brazil | 97,928 | [r]91,687 | 87,315 | 110,287 | 118,100 | [r]63,654 | 60,070 | 57,064 | 71,650 | 80,300 |
| Bulgaria | 1,726 | 1,527 | 1,775 | 2,030 | 2,070 | 529 | 467 | 545 | 612 | 615 |
| Canada[7] | 51,164 | 35,030 | 32,966 | 40,416 | 39,250 | 32,126 | 22,279 | 20,964 | 25,664 | 24,730 |
| Chile | [r]8,380 | [r]6,368 | 5,880 | 7,004 | [e]6,407 | [r]5,108 | [r]3,813 | 3,545 | 4,183 | [e]3,882 |
| China[e] | 65,000 | 68,000 | 70,000 | 74,000 | 79,000 | 32,500 | 34,000 | 35,000 | 37,000 | 39,000 |
| Colombia | [r]426 | 463 | 449 | 434 | 490 | 192 | 209 | 202 | 195 | 220 |
| Czechoslovakia | 1,904 | 1,832 | 1,873 | 1,839 | 1,870 | 494 | 475 | 482 | 473 | 480 |
| Denmark[e] | 8 | 8 | -- | -- | -- | 3 | 3 | -- | -- | -- |
| Egypt | 1,912 | 2,106 | 2,188 | [e]2,461 | 2,460 | 956 | 1,053 | 1,094 | [e]1,230 | 1,230 |
| Finland[8] | 1,211 | 1,218 | 1,257 | 1,212 | 1,180 | 777 | 774 | 809 | 776 | 740 |
| France | 21,257 | 19,085 | 15,678 | 14,605 | [e]14,744 | 6,693 | 6,088 | 4,981 | 4,606 | 4,580 |
| German Democratic Republic[9] | 39 | 39 | 39 | 39 | 39 | 20 | 20 | 20 | 20 | 20 |
| Germany, Federal Republic of | 1,547 | [r]1,298 | 961 | 962 | [e]1,018 | [r]468 | 380 | 275 | 288 | [e]304 |
| Greece[5] | 1,252 | 508 | 1,322 | 1,899 | 1,870 | 538 | 218 | 563 | 797 | 790 |
| Hungary | 415 | 460 | 434 | 377 | 310 | 99 | 110 | 104 | 91 | 74 |
| India | 40,698 | 40,256 | [e]38,187 | 40,378 | [e]43,842 | 25,479 | 25,201 | 23,905 | 25,276 | [e]27,446 |
| Indonesia | 86 | 142 | 131 | 82 | 120 | 49 | 82 | 76 | 47 | 70 |
| Iran[e][10] | 590 | 740 | 840 | 840 | 840 | 360 | 390 | 440 | 440 | 440 |
| Italy[11] | 121 | 3 | -- | -- | -- | 49 | [r]1 | -- | -- | -- |
| Japan | 435 | 356 | 293 | 319 | [e]335 | 270 | 221 | 182 | 199 | [e]209 |
| Kenya[12] | [e]4 | 4 | -- | -- | -- | [e]2 | [e]2 | -- | -- | -- |
| Korea, North[e] | 7,900 | 7,900 | 7,900 | 7,900 | 7,900 | 3,200 | 3,200 | 3,200 | 3,200 | 3,200 |
| Korea, Republic of | 585 | 610 | 645 | 615 | 530 | 328 | 342 | 361 | 344 | 290 |
| Liberia | 19,393 | 17,878 | 14,701 | 14,862 | 15,100 | 12,000 | 11,082 | 9,114 | [e]9,212 | 9,330 |
| Luxembourg | 422 | -- | -- | -- | -- | 148 | -- | -- | -- | -- |
| Malaysia | 524 | [r]336 | 112 | 191 | 230 | 320 | 205 | 69 | 117 | 139 |
| Mauritania[13] | 8,567 | 8,125 | 7,268 | 9,377 | 9,800 | 5,160 | 4,675 | [e]4,183 | 5,663 | 4,900 |
| Mexico[14] | [r]8,573 | 8,026 | 7,913 | 8,186 | 7,700 | [r]5,658 | 5,297 | 5,222 | 5,402 | 5,067 |
| Morocco | 72 | 220 | 170 | 160 | 188 | 44 | 137 | 104 | 99 | 116 |
| New Zealand[15] | 3,202 | 2,747 | 2,168 | 2,376 | 2,400 | 1,825 | 1,566 | 1,236 | 1,354 | 1,402 |
| Norway | 4,073 | 3,489 | 3,489 | 3,666 | [e]3,413 | 2,648 | 2,268 | 2,268 | 2,382 | [e]2,218 |
| Peru | 5,973 | 5,683 | 4,289 | 4,012 | [e]5,023 | 3,944 | 3,751 | 2,824 | 2,676 | 3,350 |
| Philippines | 6 | 6 | 3 | (16) | -- | 3 | 3 | 2 | (16) | -- |

See footnotes at end of table.

## Table 14.—Iron ore, iron ore concentrates, and iron ore agglomerates: World production, by country[1] —Continued

(Thousand long tons)

| Country[2] | Gross weight[3] | | | | | Metal content[4] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1981 | 1982 | 1983 | 1984[p] | 1985[e] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
| Poland | 103 | 48 | 10 | 11 | [e]11 | 29 | 14 | 3 | 3 | [e]3 |
| Portugal[17] | 36 | 27 | 35 | 35 | [e]26 | 13 | 9 | [e]11 | [r] [e]13 | 12 |
| Romania | 2,268 | 2,112 | 1,956 | [e]1,968 | 2,070 | 591 | 551 | 607 | 512 | [e]522 |
| Sierra Leone | -- | [r]65 | 396 | [e]349 | 295 | -- | 40 | 260 | [e]219 | 185 |
| South Africa, Republic of[18] | 27,872 | 24,166 | 16,343 | 24,258 | [e]24,008 | 17,837 | 15,467 | 10,459 | 15,500 | [e]15,341 |
| Spain[19] | 8,430 | [r]8,238 | 7,381 | 7,835 | [e]6,350 | 4,151 | 4,065 | 3,457 | 3,502 | [e]3,139 |
| Sweden | 22,858 | 15,888 | 13,003 | 17,837 | 20,131 | 14,835 | 10,324 | 8,452 | 11,003 | 13,085 |
| Thailand | 61 | 27 | 39 | 60 | 80 | 33 | 15 | 22 | 32 | 43 |
| Tunisia | 390 | [r]271 | 311 | 303 | [e]304 | [r]209 | [r]146 | 166 | 163 | 163 |
| Turkey | 2,889 | [r]3,007 | 3,573 | 3,985 | 3,940 | [r]1,562 | [r]1,628 | 1,935 | 2,164 | 2,138 |
| U.S.S.R | 238,589 | 240,551 | 241,328 | 243,201 | 244,100 | 129,001 | [r]129,969 | 131,454 | 132,680 | 133,160 |
| United Kingdom | 719 | 463 | 378 | 397 | 340 | 158 | 101 | 80 | 81 | 72 |
| United States[19] | 73,174 | 35,433 | 37,562 | 51,269 | 48,751 | 46,539 | 22,642 | 24,167 | 33,110 | 31,296 |
| Venezuela | 15,286 | 11,023 | 9,562 | 12,848 | 15,240 | 9,477 | 6,834 | 5,924 | 7,965 | 9,450 |
| Yugoslavia | 4,718 | 5,025 | 4,939 | 5,237 | [e]5,391 | 1,486 | 1,653 | 1,505 | [e]1,673 | 1,770 |
| Zimbabwe | 1,079 | 824 | 911 | 912 | 915 | [r]650 | [r]492 | 586 | 625 | 625 |
| Total | [r]844,606 | [r]768,011 | 726,399 | 817,428 | 845,251 | [r]487,850 | [r]440,581 | 416,083 | 472,870 | 492,276 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through Sept. 5, 1986.

[2] In addition to the countries listed, Cuba and Vietnam may produce iron ore, but definitive information on output levels, if any, is not available.

[3] Insofar as availability of sources permits, gross weight data in this table represent the nonduplicative sum of marketable direct-shipping iron ores, iron ore concentrates, and iron ore agglomerates produced by each of the listed countries. Concentrates and agglomerates produced from imported iron ores have been excluded, under the assumption that the ore from which such materials are produced has been credited as marketable ore in the country where it was mined.

[4] Data represent actual reported weight of contained metal or are calculated from reported metal content. Estimated figures are based on latest available iron ore content reported, except for the following countries for which grades are Bureau of Mines estimates: Albania, China, Denmark, Hungary, and North Korea.

[5] Nickeliferous iron ore.

[6] Reported figure.

[7] Series represent gross weight and metal content of usable iron ore (including byproduct ore) actually produced, natural weight.

[8] Includes magnetite concentrate, pelletized iron oxide (from roasted pyrite), and roasted pyrite (purple ore).

[9] Includes "roasted ore," presumably from pyrite, not separable from available sources.

[10] Year beginning Mar. 21 of that stated.

[11] Excludes iron oxide pellets produced from roasted pyrite.

[12] For cement manufacture.

[13] Gross weight is exported iron ore (Mauritania exports all of its iron ore).

[14] Gross weight calculated from reported iron content based on grade of 66% Fe.

[15] Concentrates from titaniferous magnetite beach sands.

[16] Revised to zero.

[17] Includes manganiferous iron ore.

[18] Includes magnetite ore as follows, in thousand long tons: 1981—4,175; 1982—4,253; 1983—3,414; 1984—3,780 (revised); and 1985—3,550.

[19] Includes byproduct ore.

# Iron Oxide Pigments

## By Donald P. Mickelsen[1]

U.S. mine production of crude iron oxide pigments increased in 1985 while shipments declined and total value of shipments remained practically unchanged. Total domestic shipments of natural and synthetic finished iron oxides decreased and unit values increased slightly over those of 1984. Synthetic iron oxide comprised 59% of all shipments. Reichard-Coulston Inc. filed for protection under Chapter 11 of the Federal Bankruptcy Code on October 22, 1985, and closed its plant at Bethlehem, PA. Chesapeake Specialty Products, a division of Bethlehem Steel Corp., began processing an iron oxide product in Baltimore, MD.

Paint and coatings was the largest end use for iron oxide pigments, followed, in order of ranking, by construction materials; colorants for glass and ceramics, plastics, paper and textiles, and rubber; foundry uses; industrial chemicals; ferrites; and other end uses.

Price increases proposed by several major producers had little effect on the market because of competitively priced imports that influenced continued discounting for larger orders.

The United States imported 34% more iron oxide pigments than it exported, partly owing to an 8% drop in U.S. exports of pigment-grade iron oxides from 1984 levels. Increased imports were attributed to a strong U.S. dollar compared with foreign currencies. U.S. imports of synthetic iron oxides showed another strong increase in 1985 while imports of natural iron oxides continued to decline. World mine production of natural iron oxide pigments for reporting countries increased compared with that of 1984.

**Domestic Data Coverage.**—Mine production and sales data for crude iron oxide pigments and sales data for finished iron oxide pigments and iron oxides from steel plant wastes were compiled from voluntary responses received from an annual survey of U.S. producers conducted by the Bureau of Mines. Responses for crude iron oxide mine production and sales data were received from five companies representing 100% of all producers that are known to mine and/or ship crude iron oxide pigments in the United States, as shown in table 1. Of the 17 companies canvassed for finished iron oxide pigments sales data in 1985, 100% responded, representing 100% of the total production shown in table 2. Of the five companies canvassed for sales data for iron oxides recovered from steel plant wastes, including steel plant dust and re-

**Table 1.—Salient U.S. iron oxide pigments statistics**

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Mine production ______ short tons__ | 28,731 | 28,082 | 26,499 | 29,307 | 32,234 |
| Crude pigments sold or used ______ do____ | 49,732 | 46,548 | 41,875 | 53,017 | 46,585 |
| Value ______ thousands__ | $1,743 | $2,059 | $2,427 | $2,819 | $2,826 |
| Finished pigments sold ______ short tons__ | 128,290 | 104,951 | 122,861 | 129,492 | 126,822 |
| Value ______ thousands__ | $95,799 | $84,736 | $110,662 | $122,620 | $122,716 |
| Exports ______ short tons__ | 4,967 | 9,065 | 12,661 | 32,428 | 29,720 |
| Value ______ thousands__ | $11,704 | $17,795 | $20,692 | $31,832 | $27,574 |
| Imports for consumption ______ short tons__ | 39,661 | 25,855 | 30,747 | 38,239 | 39,799 |
| Value ______ thousands__ | $18,915 | $13,330 | $16,684 | $21,523 | $22,565 |

generator oxide, 100% responded, representing 34% of the estimated production shown in the text discussion under "Domestic Production." Remaining data were estimated through analysis of industry trends and practices.

## DOMESTIC PRODUCTION

Mine production of crude iron oxide pigments increased 10% over 1984 levels while shipments decreased 12% and total value of shipments remained practically unchanged. One company in Georgia mined and shipped ocher and umber; magnetite was mined and shipped by a company in Missouri; and of two companies in Virginia, one mined and shipped sienna and umber and the other shipped umber. Cleveland-Cliffs Iron Co. continued to ship hematite from a stockpile at its Mather Mine in northern Michigan, which permanently closed in 1979.

Total domestic shipments of finished iron oxide pigments, excluding regenerator oxide, steel plant dust, and magnetic iron oxide, remained virtually unchanged in quantity and value when compared with that of 1984. Synthetic iron oxides comprised 59% of total shipments, the same as that of 1984. Unit values for all categories of finished iron oxides, except for the "Other" category, increased. Natural iron oxides remained practically the same in both quantity and value when compared with that of 1984. Natural raw umber and red iron oxide underwent large and moderate increases, respectively, while raw sienna, ocher, burnt sienna, and burnt umber decreased, the total of which slightly outweighed the increases. Of the 13 natural iron oxide producers canvassed, 6 reported increases in domestic shipments while the remaining producers reported decreases. Total synthetic iron oxide shipments and value remained relatively stable, with increases in synthetic brown and red oxides offsetting decreases in synthetic yellow and other iron oxides. Only one of the six synthetic iron oxide producers canvassed reported increases in shipments.

Iron oxide for use in magnetic applications, not shown in table 2, was produced by two domestic companies. Production and shipment data are unavailable because of their proprietary nature.

An estimated 38,000 short tons[3] of steel plant byproduct iron oxides, in the form of regenerator oxide and steel plant dust, were shipped in 1985. Of the five plants canvassed, representing 34% of estimated shipments with a value of $1.2 million, two showed decreases in shipments, two showed increases, and one continued to remain inactive. The remaining steel plant wastes, while unaccounted for, are estimated to be used in the manufacture of ferrites according to officials in the industry.

In October, Reichard-Coulston filed for protection under Chapter 11 of the Federal Bankruptcy Code and permanently closed its Bethlehem, PA, plant. The 131-year-old business employed almost 100 workers as late as 1984. The plant has since been sold to the Pennsylvania Perlite Corp. and will be refitted to prepare and package perlite. Reasons for the closure were attributed to competitively priced imports and a strong U.S. dollar. Chesapeake Specialty Products, a division of Bethlehem Steel, began processing an iron oxide product at their new plant in Baltimore, MD.

**Table 2.—Finished iron oxide pigments sold by processors in the United States, by kind**

| Kind | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Natural: |  |  |  |  |
| Black: Magnetite | 5,389 | $877 | 5,440 | $908 |
| Brown: |  |  |  |  |
| Iron oxide[1] | W | W | W | W |
| Umbers: |  |  |  |  |
| Burnt | 3,432 | 2,903 | 3,135 | 2,778 |
| Raw | 1,559 | 1,151 | 1,863 | 1,340 |
| Red: |  |  |  |  |
| Iron oxide[2] | 24,648 | 4,353 | 25,913 | 4,321 |
| Sienna, burnt | 631 | 561 | 554 | 502 |
| Yellow: |  |  |  |  |
| Ocher[3] | 17,272 | 4,968 | 14,613 | 4,494 |
| Sienna, raw | 280 | 249 | 233 | 228 |
| Total | 53,211 | [4]15,063 | 51,751 | 14,571 |

See footnotes at end of table.

## Table 2.—Finished iron oxide pigments sold by processors in the United States, by kind—Continued

| Kind | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Synthetic: |  |  |  |  |
| Brown: Iron oxide[5] | 16,307 | $22,128 | 18,484 | $25,566 |
| Red: Iron oxide | 33,435 | 45,403 | 33,729 | 47,045 |
| Yellow: Iron oxide | 21,482 | 27,431 | 18,112 | 24,225 |
| Other: Specialty oxides[6] | 5,057 | 12,594 | 4,746 | 11,309 |
| Total | 76,281 | 107,556 | 75,071 | 108,145 |
| Mixtures of natural and synthetic iron oxides | W | W | W | W |
| Grand total | 129,492 | [4]122,620 | 126,822 | 122,716 |

W Withheld to avoid disclosing company proprietary data.

[1] These data are included with yellow ocher to avoid disclosing company proprietary data.

[2] Includes pyrite cinder.

[3] Includes yellow and brown iron oxides.

[4] Data do not add to total shown because of independent rounding.

[5] Includes synthetic black iron oxide.

[6] Includes mixtures of natural and synthetic iron oxides.

## Table 3.—Producers of iron oxide pigments in the United States in 1985

| Producer | Mailing address | Plant location |
|---|---|---|
| Finished pigments: |  |  |
| American Minerals Inc | Foot of Jefferson St.<br>Camden, NJ 08101 | Camden, NJ. |
| BASF Chemicals, Dyestuffs & Pigments Group. | 100 Cherry Hill Rd.<br>Parsippany, NJ 07054 | Wyandotte, MI. |
| Blue Ridge Talc Co. Inc | Box 39<br>Henry, VA 24102 | Henry, VA. |
| Chemalloy Co. Inc | Box 350<br>Bryn Mawr, PA 19010 | Bryn Mawr, PA. |
| Columbian Chemicals Co | 1600 Parkwood Circle<br>Suite 400<br>Atlanta, GA 30339 | St. Louis, MO, and Monmouth Junction, NJ. |
| DCS Color & Supply Co. Inc | 2011 South Allis St.<br>Milwaukee, WI 53207 | Milwaukee, WI. |
| Foote Mineral Co | Route 100<br>Exton, PA 19341 | Exton, PA. |
| Hoover Color Corp | Box 218<br>Hiwassee, VA 24347 | Hiwassee, VA. |
| Mobay Chemical Corp | Penn Lincoln Parkway West<br>Pittsburgh, PA 15205 | New Martinsville, WV. |
| New Riverside Ochre Co | Box 387<br>Cartersville, GA 30120 | Cartersville, GA. |
| Pfizer Pigment Inc | 235 East 42d St.<br>New York, NY 10017 | Emeryville, CA; East St. Louis, IL; Easton, PA. |
| Prince Manufacturing Co | 700 Lehigh St.<br>Bowmanstown, PA 18030 | Quincy, IL, and Bowmanstown, PA. |
| Reichard-Coulston Inc | 1421 Mauch Chunk Rd.<br>Bethlehem, PA 18018 | Bethlehem, PA. |
| St. Joe Lead Co., Pea Ridge Iron Ore Co | 7733 Forsyth Blvd.<br>Clayton, MO 63105 | Sullivan, MO. |
| George B. Smith Color Co | Route 72, Box 396<br>Kirkland, IL 60146 | Maple Park, IL. |
| Solomon Grind-Chem Services Inc | Box 1766<br>Springfield, IL 62705 | Springfield, IL. |
| Sterling Drug Inc., Hilton-Davis Chemicals Div. | 2235 Langdon Farm Rd.<br>Cincinnati, OH 45237 | Cincinnati, OH. |
| Crude pigment: |  |  |
| Cleveland-Cliffs Iron Co., Mather Mine and Pioneer Plant (closed July 31, 1979; shipping from stockpile). | 1460 Union Commerce Bldg.<br>Cleveland, OH 44115 | Negaunee, MI. |
| Hoover Color Corp | Box 218<br>Hiwassee, VA 24347 | Hiwassee, VA. |
| New Riverside Ochre Co | Box 387<br>Cartersville, GA 30120 | Cartersville, GA. |
| St. Joe Lead Co., Pea Ridge Iron Ore Co | 7733 Forsyth Blvd.<br>Clayton, MO 63105 | Sullivan, MO. |
| Virginia Earth Pigments Co | Box 1403<br>Pulaski, VA 24301 | Hillsville, VA. |

## CONSUMPTION AND USES

Consumption data for iron oxide pigments, shown as percentages by end use of reported shipments in table 4, are estimates because some producers keep less detailed data concerning end-use breakdowns than others.

Paint and coatings, which continued to be the largest end use for iron oxide pigments, comprised 33% of all shipments and totaled 42,431 tons in 1985. Consumption decreased slightly compared with that of 1984. Preliminary data developed by the U.S. Department of Commerce[3] indicate that slightly more than 982 million gallons of coatings valued at $9.9 billion was shipped, up 7% in volume over that of 1984. Architectural coatings comprised 49% of total shipments and totaled 486 million gallons; product coatings-original equipment manufacture (OEM) was 320 million gallons, or 33% of shipments; and 18%, or 176 million gallons, was special-purpose coatings.

Usage of iron oxide pigments in construction materials remained at about the same quantity and percentage of total shipments. Consumption increased slightly from 1984 levels, to 36,179 tons, and comprised 28% of all iron oxide pigments consumed.

Twelve percent, or 15,054 tons, of all iron oxides was consumed as colorants for plastics, glass and ceramics, rubber, and paper and textiles, by order of ranking, representing a small decrease in consumption from that of 1984. One published report indicated that 4,800 tons of iron oxide was consumed in plastics in 1985, virtually the same as that of 1984.[4] Iron oxides, which are the second largest inorganic pigments consumed, are popular because of their low cost, coloring effectiveness in thermoplastics and thermosets, and because of Food and Drug Administration acceptance for food contact and medical applications.

The remaining 27% of reported iron oxide pigment consumption, by order of ranking, was in the manufacture of animal feed and fertilizers, foundry sands, industrial chemicals, ferrites, cosmetics, jewelers' rouge, and other end uses.

Regenerator oxide and steel plant dust, not accounted for in table 4, were used mainly in the manufacture of ferrites, with lesser amounts used in paint and coatings, as colorants for construction materials, and in fertilizers and foundry sands. An estimated 38,000 tons was shipped for consumption in 1985. Magnetic iron oxides, also not included in the table, were mainly used in the manufacture of magnetic media such as magnetic tapes and floppy disks, magnetic toners, and other electronic applications. Over 15,000 tons was estimated to be consumed.

**Table 4.—Estimated iron oxide pigment consumption,[1] by end use, as a percentage of reported shipments**

| End use | All iron oxides |  | Natural iron oxides |  | Synthetic iron oxides |  |
|---|---|---|---|---|---|---|
|  | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 |
| Coatings (industrial finishes, trade sales paints, varnishes, lacquers) | 35 | 33 | 25 | 22 | $^{r}$42 | 41 |
| Construction materials (cement, mortar, preformed concrete, roofing granules) | 28 | 28 | 28 | 30 | $^{r}$28 | 28 |
| Colorants for plastics, rubber, paper, textiles, glass, ceramics | $^{r}$11 | 12 | $^{r}$11 | 12 | $^{r}$11 | 12 |
| Industrial chemicals (such as catalysts) | 5 | 5 | 3 | 1 | 6 | 7 |
| Animal feed and fertilizers | $^{r}$5 | 6 | $^{r}$12 | 13 | $^{r}$2 | 1 |
| Foundry sands | 5 | 6 | $^{r}$12 | 14 | -- | -- |
| Other (including ferrites, cosmetics, and jewelers' rouge) | $^{r}$11 | 10 | $^{r}$9 | 8 | $^{r}$11 | 11 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 |

$^{r}$Revised.

[1] Data do not include magnetic iron oxide usage.

## PRICES

One major domestic producer announced price increases of approximately 5% for its line of synthetic iron oxides, effective January 1, 1985. This increase was a continuation of similar increases announced by other major producers for December 1984 because of increased production costs. Following these announced increases, list prices for natural and synthetic grades of iron oxide pigments sold by major domestic producers remained unchanged for the rest of 1985. Competition from low-priced imports and a strong U.S. dollar led to price discounting for larger accounts and in effect nullified announced 1985 price increases for these orders. In the fourth quarter, prices charged for raw sienna by other producers and distributors advanced from 36 to 44 cents to 41 to 53 cents per pound; burnt siennas advanced from 45 cents per pound to a range of 48 to 54 cents per pound; and Vandyke brown increased 3 cents to 45 cents per pound according to the American Paint and Coatings Journal.

**Table 5.—Prices quoted on finished iron oxide pigments, per pound, bulk shipments,[1] December 31, 1985**

| Pigment | Low | High |
|---|---|---|
| Black: | | |
| Natural | -- | $0.2700 |
| Synthetic | $0.6900 | .7150 |
| Micaceous | -- | .6875 |
| Brown: | | |
| Ground iron ore | .1300 | .1450 |
| Metallic | .1650 | .2950 |
| Pure, synthetic | -- | .7050 |
| Sienna, domestic, burnt | .4800 | .5400 |
| Sienna, domestic, raw | .4100 | .5300 |
| Sienna, Italian, burnt | .4500 | .7300 |
| Umber, Turkish, burnt | .4350 | .5200 |
| Vandyke brown | -- | .4500 |
| Red: | | |
| Domestic primers, natural, micronized | -- | .2375 |
| Pure, synthetic | -- | .6600 |
| Spanish | -- | .2950 |
| Yellow: | | |
| Synthetic | -- | .6800 |
| Ocher, domestic | -- | .2200 |

[1] Prices shown represent the best information available but are not to be considered definite according to the source.

Source: American Paint and Coatings Journal.

## FOREIGN TRADE

The United States imported 34% more iron oxide pigments than it exported in 1985, with much of the continued trade imbalance being caused by a strong U.S. dollar compared with foreign currencies. Total value of U.S. exports of iron oxide pigments was $27.6 million, or $5.0 million greater than that of U.S. imports, however.

U.S. imports of iron oxide pigments for consumption increased 4% in quantity and 5% in value compared with those of 1984, and were received from 23 countries. Monthly import levels advanced through the first two quarters, peaked in June, and then retreated through the rest of the year. Imports of synthetic iron oxides increased 10% in quantity and 6% in value and comprised 83% of all imports received, 5% more than that for 1984. All grades of synthetic iron oxides increased in quantity, the most notable occurring in black and yellow grades, which increased 19% and 16%, respectively. The unit value for synthetic black decreased 5 to 26 cents per pound; synthetic red decreased 15 to 25 cents per pound; and synthetic yellow iron oxides decreased 10 to 19 cents per pound. Other grades of synthetic iron oxides increased 18 to 51 cents per pound, however. Synthetic iron oxides were received chiefly from the Federal Republic of Germany, Canada, Japan, Mexico, and the United Kingdom, comprising 48%, 25%, 12%, 8%, and 3% of total imports, respectively.

Periodically, iron oxide pigments also enter the United States under the combined classification, "Iron compounds, other." In 1985, iron oxides, including regenerator oxides, were received from Canada and several Western European countries.

U.S. exports of pigment-grade iron oxides and hydroxides decreased 8% in quantity and 13% in value compared with those of 1984. These exports were received by 44 countries, principally in Europe, Asia, and other North American countries. Chief destinations for iron oxide pigments, by order of ranking, were the Federal Republic of Germany, Japan, Canada, Belgium-Luxembourg, and the United Kingdom. Exports to the Federal Republic of Germany decreased 16% from those of 1984 and had an average value of 26 cents per pound, the same as that of 1984. Exports of other grades of iron oxides and hydroxides increased 39% in quantity and 4% in value compared with those of 1984. Main destinations were Japan, Oman, Indonesia, and Singapore.

U.S. imports of natural iron oxides decreased 19% in quantity and 13% in value compared with 1984 levels. The most sizable decreases, which were responsible for overall decreases in natural imports, occurred in crude and finished umbers and Vandyke brown, these categories declining 23%, 18%, and 39%, respectively, from 1984 levels. Unit values for all grades of natural crude iron oxides, finished sienna, and finished other natural iron oxide pigments increased, while all other grades decreased. Cyprus, Spain, the Federal Republic of Germany, Italy, and the United Kingdom, by order of ranking, supplied 95% of all imports of natural iron oxides. Finished umber was primarily received from Cyprus and the United Kingdom; sienna, from Cyprus and Italy; and Vandyke brown was received principally from the Federal Republic of Germany. The United States also received 20 tons of micaceous iron oxide from Austria. Minor amounts of natural crude and synthetic iron oxides were received and stored in bonded warehouses for future consumption.

**Table 6.—U.S. exports of iron oxides and hydroxides, by country**

| Country | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Pigment grade | | Other grade | | Pigment grade | | Other grade | |
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Algeria | 115 | $88 | -- | -- | -- | -- | -- | -- |
| Argentina | 8 | 26 | (1) | $2 | 2 | $9 | -- | -- |
| Australia | 97 | 148 | 263 | 598 | 45 | 89 | 186 | $532 |
| Belgium-Luxembourg | 250 | 357 | 113 | 207 | 2,126 | 1,099 | 319 | 465 |
| Brazil | 176 | 657 | 137 | 530 | 91 | 259 | 158 | 542 |
| Bulgaria | (1) | 1 | 27 | 59 | 44 | 98 | -- | -- |
| Canada | 2,521 | 3,659 | 186 | 372 | 2,171 | 2,983 | 274 | 441 |
| Colombia | 61 | 41 | 19 | 30 | 59 | 48 | 11 | 17 |
| Denmark | 17 | 54 | 2 | 2 | 3 | 11 | 3 | 12 |
| Dominican Republic | (1) | 2 | 28 | 25 | 1 | 6 | 23 | 6 |
| Ecuador | 60 | 105 | 8 | 9 | 15 | 31 | 1 | 9 |
| Egypt | -- | -- | 33 | 20 | -- | -- | 20 | 26 |
| El Salvador | 19 | 38 | 2 | 3 | 30 | 72 | 4 | 9 |
| Finland | 23 | 34 | -- | -- | 24 | 35 | 10 | 14 |
| France | 535 | 810 | 135 | 286 | 666 | 1,078 | 118 | 230 |
| Germany, Federal Republic of | 23,210 | 12,473 | 64 | 152 | 19,587 | 10,389 | 76 | 176 |
| Hong Kong | 325 | 575 | 18 | 62 | 358 | 352 | 82 | 304 |
| Indonesia | -- | -- | -- | -- | -- | -- | 616 | 269 |
| Ireland | 51 | 163 | -- | -- | 67 | 216 | -- | -- |
| Israel | 6 | 8 | 3 | 6 | -- | -- | -- | -- |
| Italy | 301 | 1,744 | 62 | 128 | 268 | 1,499 | 7 | 11 |
| Jamaica | 4 | 6 | 1 | 4 | 2 | 4 | -- | -- |
| Japan | 2,732 | 8,985 | 1,658 | 4,833 | 2,186 | 2,307 | 1,752 | 4,708 |
| Korea, Republic of | 259 | 199 | 11 | 36 | 155 | 154 | 117 | 328 |
| Libya | -- | -- | -- | -- | -- | -- | 24 | 56 |
| Malaysia | 21 | 44 | 40 | 88 | -- | -- | -- | -- |
| Mexico | 236 | 369 | 188 | 394 | 293 | 437 | 390 | 1,027 |
| Morocco | -- | -- | -- | -- | -- | -- | 33 | 50 |
| Netherlands | 60 | 200 | 56 | 201 | 115 | 180 | 62 | 159 |
| New Zealand | 8 | 14 | 11 | 26 | 16 | 38 | 19 | 46 |
| Oman | -- | -- | 204 | 164 | -- | -- | 653 | 301 |
| Panama | 30 | 38 | -- | -- | 6 | 6 | -- | -- |
| Peru | 22 | 19 | 1 | 1 | 1 | 2 | -- | -- |
| Philippines | 21 | 18 | 3 | 8 | 15 | 11 | 2 | 3 |
| Singapore | 37 | 58 | 170 | 565 | 22 | 62 | 430 | 409 |

See footnotes at end of table.

## Table 6.—U.S. exports of iron oxides and hydroxides, by country —Continued

| Country | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Pigment grade | | Other grade | | Pigment grade | | Other grade | |
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| South Africa, Republic of | 11 | $24 | 1 | $5 | 7 | $15 | -- | -- |
| Spain | 12 | 30 | 33 | 72 | 11 | 42 | -- | -- |
| Sweden | 6 | 43 | 4 | 10 | 1 | 2 | 10 | $23 |
| Switzerland | 24 | 84 | 1 | 4 | 20 | 48 | -- | -- |
| Taiwan | 42 | 168 | 21 | 46 | 65 | 177 | 94 | 214 |
| Thailand | 24 | 29 | 2 | 4 | 19 | 15 | 4 | 4 |
| Tunisia | -- | -- | 58 | 78 | -- | -- | -- | -- |
| Turkey | 16 | 160 | -- | -- | -- | -- | -- | -- |
| United Arab Emirates | -- | -- | 10 | 14 | -- | -- | 38 | 63 |
| United Kingdom | 896 | 4,920 | 313 | 732 | 1,073 | 5,424 | 274 | 543 |
| Uruguay | 10 | 11 | 6 | 4 | 5 | 6 | -- | -- |
| Venezuela | 158 | 361 | 340 | 1,029 | 133 | 292 | 42 | 144 |
| Yemen, Aden | -- | -- | -- | -- | -- | -- | 55 | 104 |
| Yemen, Sana | -- | -- | -- | -- | -- | -- | 20 | 43 |
| Yugoslavia | -- | -- | 48 | 84 | -- | -- | -- | -- |
| Other | 25 | 69 | 10 | [r]15 | 18 | 78 | 23 | 76 |
| Total[2] | 32,428 | 31,832 | 4,292 | 10,909 | 29,720 | 27,574 | 5,953 | 11,364 |

[r] Revised.

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## Table 7.—U.S. imports for consumption of selected iron oxide pigments, by type

| Pigment | 1984 | | 1985 | | Major sources, 1985 |
|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | |
| Natural: | | | | | |
| Crude: | | | | | |
| Ocher | 7 | $31 | 1 | $6 | Japan 1. |
| Sienna | 38 | 22 | 225 | 30 | Italy 225. |
| Umber | 5,963 | 860 | 4,564 | 674 | Cyprus 4,526; France 26; Canada 11. |
| Other | 134 | 142 | 150 | 248 | Canada 43; Cyprus 40; Panama 23; Japan 19; France 10. |
| Total[1] | 6,143 | 1,054 | 4,940 | 957 | |
| Finished: | | | | | |
| Ocher | (2) | (2) | 25 | 16 | Spain 22; France 3. |
| Sienna | 122 | 50 | 45 | 19 | Cyprus 26; Italy 19. |
| Umber | 438 | 152 | 357 | 121 | Cyprus 204; United Kingdom 105; West Germany 40; Canada 8. |
| Vandyke brown | 659 | 244 | 404 | 140 | West Germany 362; Netherlands 21; Belgium-Luxemburg 21. |
| Other | 862 | 302 | 876 | 313 | Spain 734; Netherlands 75; Australia 20; Austria 20; West Germany 20. |
| Total[1] | 2,081 | 748 | 1,707 | 608 | |

See footnotes at end of table.

## Table 7.—U.S. imports for consumption of selected iron oxide pigments, by type —Continued

| Pigment | 1984 |  | 1985 |  | Major sources, 1985 |
|---|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |  |
| Synthetic: |  |  |  |  |  |
| Black | 614 | $386 | 733 | $386 | West Germany 376; United Kingdom 162, Netherlands 99; Belgium-Luxemburg 40; Canada 26. |
| Red | 5,690 | 4,634 | 5,724 | 2,835 | West Germany 2,100; Japan 1,407; Mexico 808; Canada 616; United Kingdom 400; Brazil 250. |
| Yellow | 12,978 | 7,525 | 15,011 | 5,773 | West Germany 11,664; Mexico 1,708; Canada 665; United Kingdom 279; Brazil 182; Belgium-Luxemburg 180. |
| Other[3] | 10,733 | 7,174 | 11,684 | 12,005 | Canada 6,985; Japan 2,435; West Germany 1,724; Netherlands 317; United Kingdom 117. |
| Total[1] | 30,015 | 19,720 | 33,151 | 20,999 |  |
| Grand total[1] | 38,239 | 21,523 | 39,799 | 22,565 |  |

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 1/2 unit.

[3] Includes synthetic brown oxides, transparent oxides, and magnetic and precursor oxides.

Source: Bureau of the Census.

## Table 8.—U.S. imports for consumption of iron oxide and iron hydroxide pigments, by country

| Country | Natural |  |  |  | Synthetic |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  | 1984 |  | 1985 |  | 1984 |  | 1985 |  |
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Australia | -- | -- | 20 | $10 | -- | -- | -- | -- |
| Austria | 122 | $64 | 20 | 9 | -- | -- | -- | -- |
| Belgium-Luxembourg | 9 | 6 | 21 | 7 | 218 | $65 | 303 | $102 |
| Brazil | -- | -- | -- | -- | 300 | 163 | 432 | 235 |
| Canada | 12 | 64 | 62 | 28 | 8,851 | 2,550 | 8,292 | 2,230 |
| Cyprus | 5,772 | 889 | 4,796 | 742 | -- | -- | -- | -- |
| Denmark | -- | -- | -- | -- | -- | -- | 11 | 10 |
| Dominican Republic | -- | -- | -- | -- | -- | -- | 60 | 16 |
| France | 2 | 27 | 41 | 60 | 2 | 10 | 3 | 16 |
| Germany, Federal Republic of | 688 | 269 | 422 | 177 | 13,678 | 6,936 | 15,864 | 7,997 |
| Ireland | 63 | 9 | -- | -- | -- | -- | 21 | 14 |
| Italy | 80 | 40 | 245 | 37 | 16 | 12 | -- | -- |
| Japan | 18 | 76 | 28 | 157 | 4,146 | 8,176 | 3,963 | 7,826 |
| Mexico | 68 | 47 | -- | -- | 1,603 | 789 | 2,527 | 1,350 |
| Netherlands | 52 | 52 | 96 | 79 | 194 | 79 | 489 | 226 |
| Norway | -- | -- | -- | -- | 24 | 19 | -- | -- |
| Portugal | 117 | 17 | -- | -- | -- | -- | -- | -- |
| Spain | 660 | 121 | 756 | 159 | 116 | 22 | 143 | 45 |
| Sweden | -- | -- | 6 | 10 | 20 | 378 | 17 | 349 |
| Switzerland | 1 | 1 | -- | -- | 12 | 26 | 15 | 11 |
| United Arab Emirates | -- | -- | -- | -- | -- | -- | 20 | 10 |
| United Kingdom | 559 | 119 | 111 | 47 | 817 | 482 | 958 | 545 |
| Other | 1 | 1 | 25 | 43 | [r]18 | [r]14 | 33 | 17 |
| Total[1] | 8,224 | 1,802 | 6,647 | 1,566 | 30,015 | 19,720 | 33,151 | 20,999 |

[r] Revised.

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

World mine production of natural iron oxide pigments for reporting countries increased 10% compared with that of 1984. In addition to these countries, other countries undoubtedly produce natural iron oxide pigments including, but not limited to, the centrally planned economy countries. Natural red iron oxide was produced primarily by India and Spain; yellow ocher was produced principally by France, Spain, the Republic of South Africa, and the United States; and sienna was mainly produced by Cyprus and Italy. Cyprus was the major umber producer, Austria was the principal micaceous iron oxide producer, and the Federal Republic of Germany was the main Vandyke brown producer.

Synthetic iron oxides comprise the largest percentage of colored inorganic pigment production in the world. Their popularity is attributed to performance/price relationship. Iron oxides exhibit high tinctorial strength and hiding power, chemical resistance, lightfastness, and weatherfastness at low pigmentation costs. Synthetic iron oxides have also made continuous gains in total market share over natural iron oxides because of product consistency, higher tinting strengths, and more saturated color shades compared with natural grades. Principal world producers of synthetic iron oxides include the Federal Republic of Germany, the United States, Japan, Mexico, and Brazil.

**Japan.**—Titan Kogyo Co. Ltd. of Japan developed a heat-resistant yellowish iron oxide capable of withstanding heat up to 300° C. This is 100° C higher than present commercially available iron oxides. In addition to greater heat resistance, the product has excellent weather and chemical resistance and ultraviolet ray absorption. The product consists of 0.08- to 0.8-micrometer diameter crystals and is designed for use as a colorant for plastics. Titan Kogyo began construction of a full-scale commercial plant at its Ube plant location. Completion was expected by the end of 1985.[5]

According to the Japan Inorganic Chemical Industry Association, sales of iron oxide were forecast to remain stable in 1985, totaling 172,800 tons. This follows a 22% jump in sales from 1983 to 1984. Magnetic material end uses were expected to continue to dominate iron oxide sales comprising 76% of the total or 131,000 tons. The largest consumer of magnetic materials is the electronics industry, which underwent a slump in the second quarter of 1985. Little growth was expected in 1985 in sales of office automation, audio, and visual equipment, and demand for hard and soft ferrites and magnetic material were forecast to remain stable. Other major areas for domestically produced iron oxide and their projected end-use sales were paints, roads, printing inks, construction materials, synthetic resin, ceramics, paper and other uses, by order of rank. In 1985, 18 companies at 19 locations manufactured ferric oxide.[6]

Published statistics indicate that iron oxide production for the first 7 months of 1985 totaled 96,953 tons, 6% greater than that for the comparable period in 1984. Monthly production capacity for the same period increased from 15,808 tons to 18,156 tons, causing capacity utilization to decrease 85.7% to 68.2%. Wholesale prices, f.o.r., remained unchanged for ferrite use iron oxides and special use iron oxides during 1985.[7] Prices were $0.83 per kilogram in 10-metric-ton delivery units and $1.74 per kilogram in 1-metric-ton shipments, respectively.[8]

**Spain.**—The major iron oxide producers in Spain are Productos Minerales para la Industria S.A. (Promindsa) and Óxidos Rojos de Málaga S.A. Promindsa's product line includes natural red iron oxide, natural yellow ocher, black magnetic iron oxide, and high-purity iron oxide (Ferrox). Hematite is mined at its underground operation in Tierga in northern Spain. Proven resources have been estimated at 2.2 million tons with exploratory work continuing. The processing plant at the minesite has an annual production capacity of 22,000 tons. Recently, as much as 13,000 tons per year of micronized red iron oxide has been produced at the plant. About 90% of Promindsa's products are exported through the ports of Bilboa, Barcelona, and Valencia, by order of ranking.

Óxidos Rojos de Málaga, a wholly owned subsidiary of Golden Valley Colours Ltd., Bristol, the United Kingdom, produces both superfine and micronized grades of natural red iron oxide from its mines in Málaga. About 6,000 tons were produced in 1984.

Other iron oxide producers are Sociedad Española de Óxidos de Pinturas, Ramón Alcalde Zorilla, and Óxidos del Sur SL. Zorilla has its own mine in Jaén, while the others purchase iron oxides for further processing. Óxidos del Sur purchases iron oxides from Almeria, Granada, and Jaén, and processes the oxides at its plant in Almeria, which has a production capacity of 3,900 tons per year. Up to 1,300 tons of granular grey micaceous iron oxide, 900 tons of platy brown micaceous iron oxide, and 1,700 tons of natural red iron oxide can be produced annually. Both wet and dry concentration methods are used depending on grade and price of material.[9]

**Table 9.—Natural iron oxide pigments: World mine production, by country[1]**

(Short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina | 815 | 1,027 | 940 | 882 | 880 |
| Australia | 925 | -- | -- | -- | -- |
| Austria | 12,478 | 10,549 | 12,935 | [e]12,700 | 11,000 |
| Brazil | 4,578 | 5,811 | 4,211 | 4,689 | 5,000 |
| Burma | 386 | -- | -- | -- | -- |
| Canada[e] | 3,100 | 3,100 | 3,100 | 3,100 | 2,200 |
| Chile | 5,390 | 2,695 | 7,442 | 17,762 | 16,500 |
| Cyprus | 22,046 | 22,046 | 17,637 | 14,440 | 14,300 |
| Egypt | [e]140 | [e]160 | -- | -- | -- |
| France[e] | 16,530 | 17,600 | 17,600 | 16,500 | 16,500 |
| Germany, Federal Republic of[e] | 24,828 | 20,491 | 21,921 | [e]22,000 | 23,000 |
| India | 87,778 | 93,464 | 97,701 | 118,886 | 119,000 |
| Iran[e] [4] | 550 | 550 | 660 | 660 | 660 |
| Italy[e] | 1,000 | 900 | 1,000 | 900 | 900 |
| Pakistan | [r]1,531 | [r]453 | 1,187 | 1,205 | 1,800 |
| Paraguay[e] | 220 | 130 | 200 | [r]275 | 220 |
| South Africa, Republic of | 1,430 | 2,355 | 1,861 | 1,092 | 770 |
| Spain: | | | | | |
| Ocher | 17,110 | 12,907 | 10,890 | [e]11,000 | 11,000 |
| Red iron oxide[e] | 27,600 | 25,000 | 22,000 | 22,000 | 22,000 |
| United States | 28,731 | 28,082 | 26,499 | 29,307 | [5]32,234 |
| Zimbabwe[e] | 1,320 | 1,100 | 1,100 | 1,100 | 1,100 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Table includes data available through Apr. 15, 1986.

[2] In addition to the countries listed, a considerable number of others undoubtedly produce iron oxide pigments, but output is not reported, and no basis is available for formulating estimates of output levels. Such countries include (but are not limited to) China and the U.S.S.R. Because unreported output is probably substantial, this table is not added to provide a world total.

[3] Includes Vandyke brown.

[4] Iranian calendar year (Mar. 21 to Mar. 20), beginning in the year stated.

[5] Reported figure.

## TECHNOLOGY

A comprehensive study was recently completed on magnetic materials by the National Materials Advisory Board of the National Research Council in response to a request from the U.S. Department of Defense. Members on the committee on magnetic materials, which conducted the study, represented major producers and universities concerned with this technological area. The committee's purpose was (1) to access current progress in research and development of magnetic materials in the United States, (2) to identify key problems and factors that may limit the use of needed future magnetic materials, and (3) to recommend research and development areas, including those in manufacturing technology, that appear most likely to return the highest scientific and technological dividends within the decade. Among the areas extensively studied were hard and soft magnetic materials; storage media, including particulate coatings and thin films, magneto-optic materials, and magnetic bubbles; magnetostriction and magnetoresistance transducers; and fine particles for uses other than recording such as electrophotography and ferrofluids.

The report concluded that, despite the critical importance of magnetic materials, the United States is rapidly losing its competitive position in major magnetic technologies because of the growing reliance by the U.S. industry on external sources for magnetic devices. Meanwhile, foreign nations, notably Japan, have invested in research and development to improve the performance of their materials, including permanent magnets, soft magnetic materials, and magnetic recording materials. Recommendations were that (1) research should be increased in support of those magnetic technologies with strong growth potential or having strategic value, (2) an effort be made to regenerate a strong university-based research program in magnetism and magnetic materials, (3) the relationships between scientific research in magnetism and magnetics technology be strengthened, and (4) a national resource center for the assimilation of information on magnetic materials should be formed.[10]

A comprehensive review of printing ink was published covering approximately 319 printing ink formulations, including pigment content, ink vehicles, varnishes, and ink suppliers.[11]

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[1] Mineral Data Specialist, Division of Ferrous Metals.

[2] Unless otherwise specified, the unit of weight in this chapter is the short ton.

[3] Bureau of the Census (Dept. of Commerce). Paint, Varnish, and Lacquer. R. M28F (monthly), 1985.

[4] Modern Plastics. Special Report: Chemicals and Additives: Colorants. V. 62, No. 9, Sept. 1985, pp. 61-62.

[5] Japan Chemical Week. Titan Kogyo Plans Mass Production of Yellowish Iron Oxide. V. 26, No. 1327, Sept. 5, 1985, p. 2.

[6] Roskill Information Services Ltd. (London). Roskill's Letter From Japan. Ferric Oxide: Sales to Ferrite and Magnetic Tape Sectors Up 31%: Little Growth Anticipated for 1985. RLJ No. 114, Oct. 1985, pp. 8-10.

[7] Japan Chemical Week (weekly).

[8] Where appropriate, values have been converted from Japanese yen (Y) to U.S. dollars at a 1985 11-month average rate of Y241.78 = US$1.00.

[9] Industrial Minerals (London). Spain's Industrial Minerals. No. 217, Oct. 1985, pp. 23-63.

[10] National Materials Advisory Board, Commission on Engineering and Technical Systems. Magnetic Materials. Natl. Res. Counc., Natl. Mater. Advis. Board, Publ. NMAB-426, Natl. Acad. Press, Washington, DC, 1985, 90 pp.

[11] Flick, E. W. Printing Ink Formulations. Noyes Publ., 1985, 184 pp.

# Iron and Steel

### By Frederick J. Schottman[1]

Despite somewhat lower imports, steel production and shipments declined, remaining at relatively low levels. The industry operated at less than two-thirds of capability. Low shipments combined with price competition resulted in losses for many companies.

A major steel company entered bankruptcy and was struck by its unionized workers when it reduced pay and benefits. Other companies entered joint ventures with foreign steel companies. Although some older plants were closed, others were modernized with continuous casters or other equipment. Five new electrolytic galvanizing lines were being built.

Imports declined somewhat because of trade restraint agreements with exporting countries. New agreements were negotiated with additional countries, and coverage of restraints was expanded and extended for exports from the European Economic Community (EEC).

World production of steel remained well below capacity, and the steel industries in most industrialized countries reduced capacity. Expansion of capacity continued in certain countries with low labor cost, particularly China and the Republic of Korea.

**Table 1.—Salient iron and steel statistics**

(Thousand short tons unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Pig iron: | | | | | |
| Production | 73,755 | 43,342 | 48,770 | 51,961 | 49,963 |
| Shipments | 74,218 | 43,449 | 49,081 | 52,164 | 50,010 |
| Annual average composite price, per ton[1] | $204.66 | $213.00 | $213.00 | $213.00 | $213.00 |
| Exports[2] | 16 | 54 | 6 | 57 | 32 |
| Imports for consumption[2] | 468 | 322 | 242 | 702 | 338 |
| Steel:[3] | | | | | |
| Production of raw steel: | | | | | |
| Carbon | 101,462 | 64,143 | 73,783 | 79,918 | 76,699 |
| Stainless | 1,743 | 1,235 | 1,750 | 1,772 | 1,683 |
| All other alloy | 17,623 | 9,198 | 9,082 | 10,838 | 9,877 |
| Total | 120,828 | [4]74,577 | 84,615 | 92,528 | 88,259 |
| Capability utilization[5] percent | 78.3 | 48.4 | 56.2 | 68.4 | 66.1 |
| Net shipments of steel mill products | 88,450 | 61,567 | 67,584 | 73,740 | 73,043 |
| Finished steel annual average composite price cents per pound[1] | 24.224 | 25.271 | 26.190 | 27.313 | 27.582 |
| Exports of major iron and steel products[2] | 3,557 | 2,367 | 1,589 | 1,413 | 1,266 |
| Imports for consumption of major iron and steel products[2] | 20,818 | 17,385 | 17,964 | 27,488 | 25,707 |
| World: Production: | | | | | |
| Pig iron | [r]553,186 | [r]503,999 | 510,211 | [p]546,317 | [e]555,222 |
| Raw steel (ingots and castings) | [r]778,948 | [r]709,668 | 730,604 | [p]782,008 | [e]788,119 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Iron Age.

[2] Bureau of the Census.

[3] American Iron and Steel Institute (AISI).

[4] Data do not add to total shown because of independent rounding.

[5] Raw steel production capability is defined by AISI as the tonnage capability to produce raw steel for a sustained full order book.

**Domestic Data Coverage.**—Domestic data for the iron and steel industry are developed by the Bureau of Mines from the annual "Blast Furnace and Steel Furnace Report." Of the 34 steel operations to which a survey request was sent, 68% responded, representing 71% of the total pig iron production shown in table 1. Production for nonrespondents was estimated using data from prior year reports and from published and privately communicated information.

**Legislation and Government Programs.**—The Environmental Protection Agency (EPA) listed coke oven emissions as hazardous air pollutants. The classification of the emissions as hazardous required strict regulation of emissions levels.

In another action, EPA proposed an August 8, 1988, deadline for ending land disposal of electric-furnace dusts that are classified as hazardous wastes. Some dusts contain toxic forms of elements such as lead, cadmium, and chromium, which may be leached into ground water. Various processes to recycle or to make the dusts nonhazardous were under study.

EPA also issued final waste water standards for the foundry industry, including iron foundries. The regulation specified the permitted discharge of certain pollutants for 28 processes used in foundries. In most cases, the best practicable technology will require high-rate recycling of process water with treatment of the fraction discharged.

## DOMESTIC PRODUCTION

Production of raw steel and shipments of finished products declined slightly, continuing at historically low levels. Raw steel production remained under 93 million short tons for the fourth consecutive year, compared with an average output of 130 million tons per year for the decade prior to 1982. As in the other years since 1982, production in 1985 reached a peak early in the year and then declined. Raw steel production exceeded 72% of capability in March but dropped below 60% in December. The American Iron and Steel Institute (AISI) estimated that the raw steel capability of the industry declined from 135.3 million tons in 1984 to 133.6 million tons in 1985.

After a temporary increase in open-hearth steel production in 1984, production in such furnaces resumed its long-term decline in 1985. Basic oxygen furnaces (BOF), electric furnaces, and open-hearth furnaces produced 58.8%, 33.9%, and 7.3%, respectively, of raw steel. Requirements for raw steel were reduced by increased imports of semifinished steel, which was finished and shipped by domestic steel companies, and by the increased use of continuous casting, which increases the ratio of finished products to raw steel. The portion of raw steel that was continuously cast rose to 42.3% from 39.6% in 1984. The ratio had doubled since 1980.

Total shipments were little changed from those of 1984. Shipments of products such as structural shapes and piling used in commercial construction were higher than those of 1984. On the other hand, shipments of products for heavy construction, industrial equipment, and machinery such as plates, structural tubing, and bars were lower. Shipments of rails and accessories dropped 25%. Shipments of oil country tubular goods were also lower. The long-term decline for shipments of tin mill products continued. Overall, shipments of sheet and strip were little changed, but there was a shift from uncoated sheet and strip to galvanized.

Domestic shipments of ferrous castings declined 7% compared with those in 1984, according to U.S. Department of Commerce data. Shipments of ductile and malleable iron and castings were little changed, but shipments of gray iron castings declined about 10%. Domestic gray iron casting producers faced competition from low-priced imports of commodity-type castings such as manhole covers. Shipments of steel castings also declined because of weakness in the domestic heavy equipment and machinery industries. Shipments included 7.165 million tons of gray iron, 2.583 million tons of ductile iron, 0.378 million tons of malleable iron, and 0.889 million tons of steel castings.

Despite cost-cutting efforts, most major steel producers continued to be unprofitable. Of the six leading integrated steel companies, which produced almost two-thirds of domestic steel, only two reported profits. Wheeling-Pittsburgh Steel Corp. (W-P) suffered losses equal to over 40% of its sales because of a strike. On the other hand, Weirton Steel Corp. had its second profitable year since becoming an independent, employee-owned company.

Employment in the steel industry continued to decline. As reported to AISI, total annual average employment declined from

236,000 workers in 1984 to 208,000 in 1985. The industry employed 151,000 workers on wages and 57,000 on salaries. Employment had declined by more than one-half since 1979. AISI reported that average employment costs for hourly employees increased 7% to $22.81 per hour. Part of the increase was recovery by workers of part of the concessions made in contract talks in 1983.

Companies reduced salaried employment and pay and sought concessions from unions. In some cases, unusual features such as profit sharing or an all-salaried work force were introduced in contracts.

The multicompany committee that for almost 30 years had negotiated industrywide, pattern-setting contracts with the United Steelworkers of America was disbanded. The committee, which had at one time included almost all the major steel companies, had been reduced to five members as companies withdrew or were expelled for deviation from the pattern contract.

W-P, the seventh largest domestic steel company, entered chapter 11 bankruptcy. Unionized workers began a 98-day strike when the company, with bankruptcy court approval, revoked its labor contract and set reduced pay and benefit levels for its workers. The strike was finally settled with a new contract that reduced employment costs by about 16%. The actual loss by the workers was considerably less than 16%, however, because much of the cost savings resulted from the termination of an underfunded pension plan. The cost of pensions under the plan was thereby shifted to the Federal Pension Benefits Guaranty Corporation. The union agreed to changes to increase productivity that would result in the layoff of some workers. W-P later closed an inactive seamless tube mill and a hot strip mill at Allenport, PA.

Other companies also restructured and closed unneeded or high-cost capacity. Inland Steel Co. began to reduce the capacity at its Indiana Harbor Works, East Chicago, IN, by about 30% by closing the plant's seven open-hearth furnaces. Inland also closed two bar mills at Indiana Harbor, reducing its involvement in the bar market. LTV Steel Co. indefinitely closed all operations at its Aliquippa, PA, plant except for a structural mill and a tinplate line. Earlier in the year, the hot strip mill and seamless tube mill at Aliquippa were permanently closed. Armco Inc. also closed a tubular goods plant at Ambridge, PA. Minimills were closed by Soule Steel Corp., Carson, CA; Marathon Steel Corp., Tempe, AZ; Hurricane Industries Inc., Sealy, TX; Green River Steel Corp., Owensboro, KY; and Kentucky Electric Steel Co., Ashland, KY. Eastmet Corp. ended production of stainless steel sheet and strip at its Eastern Stainless Steel Co. plant in Baltimore, MD, but continued to produce plate. Enduro Stainless Inc., a new company that bought a stainless steel finishing plant in Massillon, OH, from LTV Steel in 1984, went bankrupt and closed in 1985.

The structure of the industry was further changed by corporate reorganization and sales. LTV Steel reorganized its plants into three subsidiaries organized along product lines. It then offered the profitable LTV Specialty Steel Inc. subsidiary for sale to raise cash. At yearend, final arrangements were being made to sell LTV Steel's Gadsden, AL, plant as Gulf States Steel Corp. to an investment group. LTV Steel had agreed in 1984 to divest the plant in order to gain antitrust approval of the merger of LTV Steel's steel operations with Republic Steel Corp.

Birmingham Bolt Co. acquired the Mississippi Steel Div. minimill in Jackson, MS, from the Magma Corp. North Star Steel Co. bought an 80% interest in the bankrupt Ohio River Steel Corp. rolling mill, Calvert City, KY, and bought the bankrupt Hunt Steel Co. plant in Youngstown, OH. The two plants were expected to broaden North Star's product range. The Ohio River Steel mill rolled medium structural shapes, and Hunt Steel produced seamless casings for oil and gas wells.

Continental Steel Corp. filed for bankruptcy but continued in operation. Phoenix Steel Corp., which had been in bankruptcy since 1983, was bought by a group of investors. Armco was selling its aerospace and nonsteel materials divisions to improve the company's financial position, and Cyclops Corp. was selling its steel divisions. Lone Star Steel Co. was spun off to the shareholders of its parent company.

United States Steel Corp. (USS) formed a joint venture with Pohang Iron and Steel Co. Ltd. (Posco) of the Republic of Korea to own and modernize USS's Pittsburg, CA, mill. The new company will invest $300 million over 4 years for new continuous pickling, cold rolling, and annealing lines. The Pittsburg plant processed hot-rolled coil from USS's Geneva, UT, plant but was expected to shift to coil from Posco's plants when import restrictions expire in 1989.

The Timken Co. started production at its new $500 million Faircrest plant at Canton, OH. The plant is designed to produce 500,000 tons of special-quality steel per year. It has a 96-megavolt-ampere, 160-ton electric furnace, scrap preheating, and ladle refining. Bottom-poured ingots and continuous rolling are used for high quality. The plant was highly automated and used only 80 production workers per shift.

Tuscaloosa Steel Corp. completed its new $75 million rolling mill in Tuscaloosa, AL. The Steckel strip mill had a capacity of 600,000 tons per year. Initially, the plant was expected to roll 250,000 tons of slab per year imported from British Steel Corp., which was a part owner of Tuscaloosa Steel.

Two minimills were installing new technology. At its Darlington, SC, plant, Nucor Corp. operated a direct-current arc furnace and signed a contract to convert another furnace to the Consteel continuous steelmaking process. Nucor also ordered an experimental Hazelett thin-slab caster that will, if successful, allow Nucor to enter the flat-rolled market. Meanwhile, Connecticut Steel Corp. was installing equipment for a 200,000-ton-per-year "micromill" at Wallingford, CT. The plant, which was expected to start up in 1986, was to use a Korf-Stahl AG Energy Optimizing Furnace that uses coal or other carbon to melt scrap.

Bethlehem Steel Corp. was installing slab casters at Burns Harbor, IN, and Sparrows Point, MD, with startup scheduled in 1986. USS was installing a 3.3-million-ton-per-year caster at Fairfield, AL, for a 1987 startup.

The Great Lakes Steel Div. of National Steel Corp. planned to build a new two-strand slab caster at Ecorse, MI. The company will also install a ladle metallurgy station at the plant as part of a $200 million modernization project. When completed in 1987, the 2.2-million-ton-per-year caster will allow Great Lakes Steel to continuously cast 100% of its production. Seattle Steel Inc. was modernizing its plant, which it bought from Bethlehem Steel in 1984, with a continuous billet caster and a new rod mill to increase total capacity to 540,000 tons of finished steel per year in 1986.

Despite the bankruptcy of W-P, Nisshin Steel Co. Ltd. and W-P signed an agreement to build a sheet coating line at Follansbee, WV. The $50 million plant was expected to be completed in 1987. Meanwhile, construction continued on five new electrogalvanizing lines. These lines, along with the Follansbee plant, were planned to provide corrosion-resistant steel with good surface finish to the automobile and appliance industries. The new electrogalvanizing lines were being built by National Steel at Ecorse, MI, with an annual capacity of 400,000 tons; by USS and the Rouge Steel Co. subsidiary of Ford Motor Co. at Dearborn, MI, with a 560,000- to 700,000-ton capacity; by LTV Steel and Sumitomo Metal Industries Ltd. at Cleveland, OH, with a 500,000-ton capacity; by Armco at Middletown, OH, with a 200,000- to 400,000-ton capacity; and by a joint venture of Bethlehem Steel, Inland, and Pre-Finish Metals Inc. at Walbridge, OH, with a 400,000-ton capacity.

**Materials Used in Ironmaking.**—Domestic pellets charged to blast furnaces in 1985 totaled 48.0 million tons, and sinter charged amounted to 18.6 million tons. Pellets and other agglomerates from foreign sources amounted to 7.9 million tons. A total of 10.9 million tons of iron ore was consumed by agglomerating plants at or near blast furnaces, producing 18.5 million tons of agglomerates. Other materials consumed by agglomerating plants were 2.6 million tons of mill scale, 0.9 million tons of flue dust, 0.8 million tons of coke breeze, and 4.1 million tons of fluxes.

Blast furnace oxygen consumption totaled 18.0 billion cubic feet according to AISI. Blast furnaces, through tuyere injection, consumed 20.5 billion cubic feet of natural gas; 3.2 billion cubic feet of coke oven gas; 111 million gallons of oil; and 26.5 million gallons of tar, pitch, and miscellaneous fuels.

**Materials Used in Steelmaking.**—According to AISI, steelmaking furnaces consumed 4.61 million tons of lime, 0.76 million tons of limestone, 0.40 million tons of fluorspar, 0.78 million tons of other fluxes, and 126 billion cubic feet of oxygen. Metalliferous materials consumed in domestic steel furnaces, per ton of raw steel produced, averaged 1,127 pounds of pig iron, 1,113 pounds of scrap, 25 pounds of ferroalloys, and 6 pounds of ore and agglomerates. The comparable figures for 1984 were 1,109 pounds of pig iron, 1,046 pounds of scrap, 25 pounds of ferroalloys, and 6 pounds of ore and agglomerates.

## PRICES

The annual average composite price for finished steel in 1985, as reported by Iron Age, was 27.582 cents per pound, up only slightly from the average for 1984. The Iron Age composite remained unchanged from July 1984 through 1985. The composite price for pig iron remained unchanged since 1982 at $213 per ton.

Despite some easing of pressure from imports, transaction prices generally declined. As major integrated steel producers reduced production costs, they were able to reduce their sale prices in efforts to maintain or increase their market share. Discounts of 20% to 30% from list were reported for various products.

Increased competition between integrated mills and minimills tended to lower prices for special-quality bars. Some minimills were trying to improve their profitability by beginning to produce these higher quality bars with premium prices. Prices of other minimill products such as reinforcing bar were generally firm to slightly higher because of relatively strong construction activity. Reported prices for reinforcing bar were about 13 cents per pound.

Late in the year, major producers announced lower list prices for many products that were intended to bring list prices more in line with transaction prices. As announced, the lower list prices combined with reduced discounting would in effect slightly raise actual prices.

## FOREIGN TRADE

Exports of major iron and steel products from the United States declined for the fifth consecutive year. Canada was again the most important importer of U.S. steel mill products, taking over one-third of the total. Exports to Mexico increased for the second year and were about one-sixth of total exports. The high value of the dollar kept U.S. steel relatively expensive in most foreign markets. Except for local trade with Canada and Mexico, much of the steel exported was specialized high-value products. The average value of steel mill products exported was $919 per ton compared with $394 for comparable products imported.

Imports of steel mill products declined, partly because of trade restrictions. On the other hand, imports of other steel products, including fabricated steel, and imports of iron products increased. Japan continued to be the leading exporter of steel mill products, shipping 6.0 million tons, which was down about 10% from the amount shipped in 1984. Canada, the second largest supplier, exported 2.9 million tons, down from 3.2 million tons in 1984. Imports from the Republic of Korea declined from 2.2 million tons in 1984 to 1.9 million tons. Imports from the EEC increased from 6.3 million tons in 1984 to 7.0 million tons in 1985. Among the EEC countries, the Federal Republic of Germany supplied 2.4 million tons; France, 1.6 million tons; Belgium-Luxembourg, 1.1 million tons; and Italy, the United Kingdom, and the Netherlands, about 0.6 million tons each. Imports from Spain, which was to join the EEC in 1986, declined from 1.4 million tons in 1984 to 0.5 million tons. Other important suppliers included Brazil, 1.7 million tons; Sweden, 0.7 million tons; and the Republic of South Africa, Venezuela, and Romania, about 0.4 million tons each.

Continuing the program begun in 1984, steel export restraint agreements were negotiated with nine additional countries. By yearend, of the countries exporting at least 200,000 tons of steel in 1985, only Canada, Sweden, and Taiwan remained without restraint agreements. The agreements were scheduled to limit exports to the United States until October 1, 1989.

The domestic steel industry continued to bring trade complaints against countries or products not covered by restraint agreements. Many of these cases were decided in favor of the domestic industry and resulted either in additional import duties or in the negotiation of new restraint agreements.

Negotiations were conducted with the EEC to expand the coverage and extend the export restraint agreement that had been in force since 1982. Early in the year, after the United States had unilaterally imposed a quota, a new agreement was reached to restrain pipe and tube exports. In the summer, another agreement restricted exports of most other products not included in the 1982 agreement. In November, an agreement was reached to extend the 1982 agreement and the new pipe and tube agreement until October 1989, when the restraint agreements negotiated with other countries were to expire. The new agreement was expanded to include most steel mill products other than semifinished steel. When no agreement was reached on semifinished steel by yearend, the United States unilaterally imposed a quota.

## WORLD REVIEW

**Australia.**—The Broken Hill Pty. Co. Ltd. (BHP) began construction of a bar mill in Brisbane, Queensland. Plans by the Quest Corp. Pty. Ltd. for a rival minimill in Brisbane were abandoned when financing could not be obtained.

**Austria.**—Stahl-und Walzwerk Marienhutte GmbH, at its minimill in Graz, operated the first commercial wheel-and-belt rotary caster in Europe. Only two other Japanese casters of this type were in operation.

**Brazil.**—The coke ovens and billet mill at the new integrated Aço Minas Gerais S.A. (ACOMINAS) steel mill began production, but completion of other parts of the plant was delayed by lack of funds. As part of an austerity program, the Government of Brazil restricted the funds available to Siderúrgia Brasileira S.A. (SIDERBRÁS), the state-owned steel group that controls ACOMINAS. The sinter plant, blast furnace, and BOF shop were nearly complete. The equipment for section and rail mills was in storage at the plantsite, but installation was not expected to begin until at least 1987.

The sale of at least parts of the SIDERBRÁS companies to private investors was proposed to reduce the public sector debt.

Cia. Siderúrgica Belgo-Mineira S.A., controlled by Arbed S.A. of Luxembourg, started operation of a 1.1-million-ton-per-year BOF shop at its João Monlevade, Minas Gerais, plant. The shop will replace older furnaces as part of a modernization program that also includes a new continuous caster.

Brazilian producers continued to expand charcoal pig iron capacity. Four new 65,000-ton-per-year blast furnaces were being installed in northern Brazil near the new Carajás iron mine, and another 65,000-ton-per-year furnace was to begin operation in Minas Gerais State in the southeast. Most charcoal pig iron in Brazil has been produced in Minas Gerais, but deforestation there was increasing shipping distances and driving up prices to producers there. As an alternative to pig iron and to scrap, which were in short supply, a group of privately owned minimills planned building a 390,000-ton-per-year gas-fueled, direct-reduction plant near a railway that carries ore from mines in Minas Gerais.

**Canada.**—Stelco Inc. continued a $300 million modernization program for its Hilton Works in Hamilton, Ontario. A slab caster and a convertible slab-billet caster were ordered for an early 1987 startup. Other improvements included modifications to a BOF, a bar mill, and a heat treating furnace. Another billet caster was planned for late in the decade. Stelco closed several older facilities at other plants for pipe, wire, and fastener production that were no longer competitive. Sydney Steel Corp., Sydney, Nova Scotia, received $110 million from the Federal and Provincial governments to modernize its steel mill. An electric furnace, which will use pig iron from the blast furnace as well as scrap, will replace the existing open hearths, and a ladle refining unit will upgrade quality. Although the changes will reduce the plant's raw steel capacity of 1.1 million tons by about 50%, the remaining capacity would be sufficient for expected markets.

QIT-Fer et Titane Inc. was constructing a new steel shop at its Sorel, Quebec, ilmenite smelter. The $70 million project includes a BOF, a ladle refining unit, and a four-strand billet caster. The plant will produce steel from pig iron that is produced as a byproduct of titanium slag production. Up to 225,000 tons of billets per year will be sold under a 6-year contract to Ivaco Inc. for production of wire rod, and other billets will also be marketed. The plant will also supply liquid steel to a 41,000-ton-per-year steel powder plant being built by Quebec Metal Powders Ltd. (QMP). QMP has an existing plant to produce up to 56,000 tons of iron powder per year from QIT-Fer pig iron. QIT-Fer and QMP are both owned by Standard Oil Co. (Ohio).

Although Canada, unlike other major steel exporters to the United States, did not have a formal steel export restraint agreement with the United States, consultations took place between the two countries. At the request of the Canadian steel pipe producers, the Government imposed country-of-origin marking requirements on imported pipe. The producers feared that pipe from third countries would be reexported to the United States and counted as Canadian, further increasing pressure for trade restraints. Late in the year, the Government made a preliminary finding that certain oil well casings from the United States and from other countries were being dumped in Canada.

**China.**—China continued to expand its iron and steel capacity. The first stage of the new steel mill at Baoshan began production with a capacity of 3.3 million tons of raw steel per year. Plans for a third stage were officially approved. Construction starting in 1991 was to raise capacity to 11 million tons per year.

Other plants were being expanded. Second-stage construction of the Panzhihua plant would add a new blast furnace and raise steel capacity by 40% to 2.7 million tons per year. Expansion at Maanshan would triple capacity to 3 million tons per year. A new blast furnace, new BOF's, and a new plate mill were being added. Older open-hearth furnaces were to be phased out as the BOF's became operational. Raw steel capacity at Handan was to be raised from 1.1 to 1.5 million tons per year.

China was attempting to minimize the cost of its expansion program by buying used equipment. Two rebuilt electric furnaces and a rod mill were bought from U.S. companies.

**Egypt.**—Alexandria National Steel Co.'s new El Dikheila plant on the outskirts of Alexandria was nearing completion for a 1986 startup. The plant will have an 800,000-ton-per-year Midrex direct-reduction unit, a 900,000-ton-per-year melt shop, and bar and rod mills.

**European Economic Community.**—The EEC countries agreed to extend their system of steel market controls for up to 3 years after their original expiration at the end of 1985. The 3-year period was to be used to phase out the controls gradually to avoid the disruption of a sudden return to a free market. The controls included production quotas, minimum prices, and import restraints. The EEC reaffirmed that investment and operating subsidies by governments would not be permitted after the end of 1985, although aid for research, pollution control, and plant closings would be allowed in some circumstances.

The EEC continued to restrict imports of steel, using quotas and bilateral agreements with exporting countries. In general, the new agreements negotiated in 1985 would allow about 3% more steel to be exported in 1986. Special agreements were negotiated with Spain and Portugal, which were to join the EEC in 1986. Exports from Spain and Portugal to other EEC countries were to be restricted during a transition period during which those countries were to be allowed to subsidize the restructuring of their steel industries.

**Finland.**—Outokumpu Oy planned to install a $100 million hot strip mill at its stainless steel plant in Tornio. Production of stainless steel began in 1976, but slabs were shipped to other companies for hot rolling. The mill was expected to operate in late 1987.

**France.**—The two major state-owned steel companies, Union Sidérurgique du Nord et de l'Est de la France S.A. (Usinor) and Société Aciéries et Laminoirs de Lorraine (Sacilor), continued to restructure. The companies were evolving into holding companies as they set up their operating parts as subsidiaries. The Government of France provided over $2 billion in assistance to strengthen the companies financially before the EEC deadline for such aid. Ownership of two jointly owned subsidiaries of Usinor and Sacilor was shifted entirely to Sacilor as part of the arrangement dividing state aid between the two companies. The two subsidiaries, Ascométal and Unimétal, had been set up in 1984 by merging parts of the bar, rod, and wire operation of Usinor and Sacilor.

**Germany, Federal Republic of.**—A proposed merger between Krupp-Stahl AG and Klöckner Werk AG was called off, reportedly because the companies and the Federal Government could not agree on the amount of financial aid the merged company would receive to cover the cost of plant closings and layoffs. Regional governments reportedly opposed the merger because of job losses. After the breakdown of merger talks, Krupp-Stahl and Klöckner planned their own rationalization programs. Krupp-Stahl planned to reduce its employment by 2,000 from 28,000 by the end of 1987.

The Saarland regional government was trying to work out a plan to keep Arbed Saarstahl GmbH out of bankruptcy. The plan would transfer controlling ownership of Arbed Saarstahl from Arbed SA of Luxembourg to a trust with a Saar bank. Arbed Saarstahl would be managed by AG der Dillenger Huttwerke, another Saar steelmaker.

**India.**—The Steel Authority of India Ltd. continued its expansion and modernization programs. Major expansions at Bhilai and Bokaro were to raise capacity at each plant to 4.4 million tons of raw steel per year. Other mills were being modernized.

Work on the new steel mill at Vishakhapatnam, the Government's other major steel project, was proceeding but was slowed by lack of funds. Alternative scaled-down plans were proposed for possible new integrated plants at Vijayanagar and Daitari.

A 170,000-ton-per-year SL/RN direct-reduction plant was ordered by Bihar Sponge Iron for installation at Chandil, Bihar. The plant was intended to supply iron to existing minimills in the region.

**Ireland.**—Union workers at the Irish Steel Ltd. minimill accepted a wage freeze and a reduction in employment in order to keep Ireland's only steel mill open. Although the EEC had approved financial aid, the Irish Government refused to provide assistance unless labor costs were reduced.

**Italy.**—Production of iron and steel was restarted at the Cornigliano works, near Genoa, of Ste. Finanziaria Siderurgica p.A. (Finsider) to produce billets for Finsider plants and for private steelmakers. Cornigliano had been shut down when its production quota for sheet had been used to reopen the Bagnoli plant in 1984. Higher costs for electricity and scrap made billets from Cornigliano attractive as a substitute for steel made in electric-furnace plants. Privately owned Acciaierie e Ferriere Lombarde Falck S.p.A. offered to close its hot strip mill near Milan and to transfer its production quota to Bagnoli in exchange for a Finsider plate plant and financial assistance from the Italian Government. Similarly, minimills received assistance in closing excess uneconomical electric furnace capacity.

**Japan.**—The Japanese steel industry planned slightly lower capital spending in fiscal 1985, the third consecutive drop. Most spending was intended to improve quality or productivity. Major steel companies were diversifying into nonsteel areas because of increasing difficulty competing in international markets. Nippon Steel Corp., the largest steel company in Japan, proceeded with its planned capacity reduction. Nine inactive blast furnaces were to be scrapped. Sumitomo Metal Industries Ltd. planned a 3-year program that was to reduce employment by 14%. Tokyo Steel Manufacturing Co. Ltd., the largest nonintegrated steel company in Japan, closed its Senju plant in Tokyo because of inadequate sales in export markets.

**Korea, Republic of.**—Construction of ironmaking and steelmaking facilities began on the new Kwangyang integrated steel mill of Posco. The first stage, with a capacity of 3 million tons of raw steel per year, was scheduled to be completed in June 1987, and a second stage, by the end of 1988. The plant is designed for eventual expansion to 13 million tons of capacity per year. Posco was also adding a second cold-rolling mill, with a capacity of 1 million tons per year, and a third continuous caster at its Pohang plant.

**Libya.**—Construction continued on the 1.2-million-ton-per-year Misratah plant, with startup expected in 1986. The plant will use natural-gas-based direct reduction to provide iron for electric-furnace steelmaking.

**Malaysia.**—A 660,000-ton-per-year direct-reduction plant began operation at the new Perwaya Terengganu Sdn. Bhd. steelworks, a joint venture firm of Heavy Industries Corp. of Malaysia Bhd. The plant is the first commercial user of direct-reduction technology developed by Nippon Steel. The steelworks had three 80-ton electric furnaces and ordered a 280,000-ton-per-year section mill.

**Mexico.**—Raw steel production declined 3% because of continued weakness of the domestic economy and a 54% drop in exports. Most of the decline in exports was because of the restraint agreement limiting exports to the United States.

Construction of the second stage of the Siderúrgica Lázaro Cárdenas-Las Truchas S.A. (SICARTSA) works at Las Truchas, Michoacán, was slowed because of Federal Government budget reductions. The works, which were to begin some operations in late 1985, included a 2.2-million-ton-per-year HYL III direct-reduction plant, four 220-ton electric furnaces, three two-strand slab casters, and a plate mill.

Tubos de Acero de México S.A. (TAMSA) was building a 660,000-ton-per-year electric-furnace melt shop to supply its seamless tube mill. It also planned to double its direct-reduced iron capacity to 770,000 tons per year in order to reduce its need for scrap. Another company, Productora Mexicana de Tuberia, began production of large-diameter linepipe at its new mill at Lázaro Cárdenas. The 330,000-ton-per-year plant was planned to use plate from the new SICARTSA plate mill. The company is owned by Siderúrgica Mexicana S.A. (SIDERMEX), which is the Government's steel industry holding company, by the Mexican development bank, and by a consortium of Japanese companies.

**New Zealand.**—New Zealand Steel Ltd. expected to complete the expansion of its raw steel capacity from 160,000 to 800,000 tons per year. The company was also adding new rolling mills for plate and sheet, which were scheduled to start up in 1986.

**Norway.**—The Christiania Spigerverk steel mill of Elkem A/S was merged with state-owned A/S Norsk Jernverk (NJ). In return, Elkem received a payment plus a 20% interest in NJ.

A rotary kiln direct-reduction plant was being installed at the K/S Ilmenittsmelteverket A/S plant to produce iron from ilmenite ore.

**Portugal.**—State-owned Siderurgia Nacional EP received approval to modernize its Seixal works near Lisbon. A new six-strand continuous caster was to be installed, and the BOF and a rolling mill were to be upgraded. The caster is part of the equipment ordered, and then put in storage, for a large-scale expansion plan that was canceled in 1982 because of the steel market downturn. Portugal was trying to modernize its industry before Government subsidies are forbidden after Portugal joins the EEC.

**South Africa, Republic of.**—South African Iron and Steel Industrial Corp. Ltd. (Iscor) ordered a KR process ironmaking plant for its Pretoria works. The 330,000-ton-per-year plant would be the first commercial application of the new technology to produce molten pig iron using noncoking coal. Because the Republic of South Africa lacks sufficient high-grade coking coals, Iscor was shutting down blast furnaces and replacing their output with direct-reduced and KR iron. In other modernization, Iscor commissioned two 140-ton electric furnaces at Pretoria. The furnaces were bought secondhand from British Steel.

**Spain.**—Restructuring of the Spanish steel industry continued as Spain prepared to join the EEC. Altos Hornos de Vizcaya S.A. started up a new meltshop with three 110-ton BOF's and two of three continuous casters being built at the Sestao works near Bilbao. Spain's largest steel company, Empresa Nacional Siderúrgica S.A. (ENSIDESA), was modernizing its Avilés plant with a new 2.8-million-ton-per-year, two-vessel BOF shop. The new shop will replace two older shops. Two continuous casters were also being installed, and the hot strip mill was being modernized. Siderúrgica del Mediterráneo, a newly created subsidiary of ENSIDESA, took over the cold-rolling mill and a new electrogalvanizing line being built at the Sagunto works of Altos Hornos del Mediterráneo S.A. (AHM). The blast furnaces and BOF's at AHM were closed down. Olarra S.A., a specialty steelmaker, started operating a new 30-ton electric furnace, replacing three smaller units, and a new rolling mill. It also began installation of a horizontal continuous caster.

Spanish steel producers were modernizing to reduce costs in preparation for Spain's entry into the EEC. During the 3-year transition period beginning in 1986, Spain's exports to other EEC countries were to be limited by quotas, while other EEC countries could ship freely into the Spanish market.

**Sweden.**—Continuing the restructuring begun in 1984, Avesta AB closed a cold-rolling strip mill at Avesta and the melt shop at Fagersta. Avesta AB is the descendant company from the merger of most of the Swedish stainless steel industry in 1984.

**Turkey.**—A third blast furnace and a third BOF increased the capacity of the state-owned Iskenderun plant from 1.3 to 2.4 million tons per year. A continuous bloom caster and two new rolling mills were also being added. The Government also approved plans to expand its other plant at Karabük.

**U.S.S.R.**—A new 5-year plan, beginning in 1986, emphasized modernization and quality improvements rather than higher production in the iron and steel industry. Up to 33 million tons of capacity in open-hearth furnaces, which still produced over one-half of Soviet steel in 1985, was to be replaced by BOF's or electric furnaces. Continuous casting was to be more than doubled to improve yield. Production of more sophisticated products such as specialty steels, oil country tubular goods, and high-quality cold-rolled and coated sheet was to be increased in order to satisfy increased demand and to reduce reliance on imports.

A $975 million contract was signed with an Italian company to build an 800,000-ton-per-year oil country tubular goods mill at Volzhskiy. The plant was to have a 1.1-million-ton-per-year electric-furnace shop, which will supply rounds to an existing pipe mill as well as to the new mill.

The second of four Midrex direct-reduction furnaces came on-line at the Oskol Electro-Metallurgical Combine (OEMK) in Kursk. Two additional units under construction will bring capacity to 1.8 million tons per year. Eventually, capacity is planned to be tripled with the addition of eight more units. The OEMK works included a pelletizing plant, electric furnaces, and rolling mills for producing specialty steels.

In 1985, two new minimills started production at Rybnitsa, Moldavia, and at the Komsomol'sk-na-Amure plant in the Far East. The new minimills are part of a shift away from the very large integrated steelworks that the U.S.S.R. has traditionally built.

## TECHNOLOGY

Development continued on casting thin slab or strip. The U.S. Department of Energy provided funding for two projects. In the first, USS and Bethlehem Steel were jointly trying to cast slab less than 1 inch thick using a Hazelett double-belt casting machine. In the second, Westinghouse Electric Corp. and Armco were developing a process to cast thin strip onto a large wheel. Allegheny Ludlum Steel Corp. was independently working on a similar process.[2] Nucor was trying to commercialize the Hazelett process for products where surface quality is not critical.

New steelmaking technology was beginning commercialization. Plasma furnaces, compared to conventional electric furnaces, offered savings on electrode costs, low noise, low shock load on the electrical system, and better yield.[3] The development of alternating current plasma torches offered the possibility of lower cost plasma furnaces.[4] Higher productivity could be obtained from a conventional electric furnace using the Consteel process. In the process, scrap is fed to the furnace almost continuously, except just before tapping, and the furnace is run at full power continuously.[5] As an alternative to electric furnaces, the energy-optimizing furnace could offer lower cost melting of scrap. In the process, energy is obtained from carbonaceous fuel injected through submerged tuyeres and energy efficiency is increased by preheating the scrap.[6]

Alternative processes for smelting iron were being tested. Allis-Chalmers Corp. tested a combined pelletizing and direct-reduction system. Hot pellets from a traveling grate furnace were fed directly to a coal-fired rotary kiln for reduction.[7] A joint research project supported by Pickands Mather & Co., Westinghouse, and Minnesota Power & Light Co. investigated a plasma process for producing molten iron from iron ore concentrates. Low-grade carbonaceous materials can be used as reductants.[8] A cold-bonding process to produce self-reducing pellets was demonstrated. Because the carbonaceous reductant is mixed with the iron oxide, the reduction reaction is rapid. The pellets can be reduced in a conventional blast furnace or hot-blast cupola to produce molten iron, or in a rotary kiln to produce sponge iron. The process was reportedly suitable for recycling steel plant wastes.[9]

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[1] Physical scientist, Division of Ferrous Metals.

[2] 33 Metal Producing. Three "Thin" Ways To Trim Steel's Hot End. V. 23, No. 4, Mar. 1985, pp. 46-49.

[3] Knoppek, T. Initial Results From the Voest-Alpine Plasma Furnace. Iron and Steel Eng., v. 62, No. 5, May 1985, pp. 23-26.

[4] Neuschutz, D., H. Rossner, H. J. Bebber, and J. Hartwig. Development of 3-Phase A-C Plasma Furnaces at Krupp. Iron and Steel Eng., v. 62, No. 5, May 1985, pp. 27-33.

[5] Vallomy, J. A. Continuous Electric Furnace Steelmaking—The CONSTEEL Process. Iron and Steel Eng., v. 62, No. 11, Nov. 1985, pp. 44-47.

[6] Bonestall, J. E., and R. Weber. EOF (Energy Optimizing Furnace) Steelmaking. Iron and Steel Eng., v. 62, No. 10, Oct. 1985, pp. 16-22.

[7] 33 Metal Producing. A "New" Direction in Direct Reduction. V. 23, No. 4, Apr. 1985, p. 70.

[8] Peters, H. Making the Most of Mesabi Ore. Met. Bull. Monthly, Mar. 1985, pp. 11-17.

[9] Weiss, F. J., A. Goksel, and F. T. Kaiser. Production of Hot Metal From Carbon-Bearing Iron Oxide Pellets by the Pelle Tech (PTC) Process. Iron and Steel Eng., v. 63, No. 2, Feb. 1986, pp. 34-40.

## Table 2.—Pig iron produced and shipped in the United States in 1985, by State

| State | Production (thousand short tons) | Shipped from furnaces |  | Average value per ton at furnace |
|---|---|---|---|---|
|  |  | Quantity (thousand short tons) | Value (thousands) |  |
| Alabama, Kentucky, Maryland | 6,745 | 6,774 | $1,442,050 | $212.88 |
| Illinois | 2,921 | 2,921 | 480,795 | 164.60 |
| Indiana | 15,651 | 15,649 | 3,215,206 | 205.46 |
| Michigan | 4,770 | 4,772 | 845,942 | 177.27 |
| Ohio | 9,259 | 9,260 | 1,900,897 | 205.28 |
| Pennsylvania | 6,473 | 6,490 | 1,366,820 | 210.60 |
| Texas, Utah, West Virginia | 4,144 | 4,145 | 873,513 | 210.74 |
| Total[1] or average | 49,963 | 50,010 | 10,125,222 | 202.46 |

[1] Data may not add to totals shown because of independent rounding.

## Table 3.—Foreign iron ore and manganiferous iron ore (excluding agglomerates) consumed in manufacturing pig iron in the United States, by source

(Thousand short tons)

| Source | 1984[1] | 1985[2] |
|---|---|---|
| Brazil | 679 | 40 |
| Canada | 256 | 1,456 |
| Venezuela | 994 | 1,202 |
| Other countries | 114 | 92 |
| Total | 2,043 | 2,790 |

[1] Excludes 10,054,084 tons used in making agglomerates.
[2] Excludes 9,798,277 tons used in making agglomerates.

## Table 4.—Pig iron shipped from blast furnaces in the United States, by grade[1]

| Grade | 1984 |  |  | 1985 |  |  |
|---|---|---|---|---|---|---|
|  | Quantity (thousand short tons) | Value |  | Quantity (thousand short tons) | Value |  |
|  |  | Total (thousands) | Average per ton |  | Total (thousands) | Average per ton |
| Basic | 51,526 | $10,065,652 | $195.35 | 49,333 | $9,990,377 | $202.51 |
| Foundry | W | W | W | W | W | W |
| All other (not ferroalloys) | 637 | 128,533 | 201.78 | 677 | 134,845 | 199.18 |
| Total or average | [2]52,164 | 10,194,185 | 195.43 | 50,010 | 10,125,222 | 202.46 |

W Withheld to avoid disclosing company proprietary data; included with "All other."
[1] Includes molten iron transferred directly to steel furnaces.
[2] Data do not add to total shown because of independent rounding.

## Table 5.—Iron ore and other metalliferous materials, coke, and fluxes consumed in blast furnaces, and pig iron produced in the United States, by State

(Thousand short tons unless otherwise specified)

| State | Metalliferous materials consumed in blast furnaces | | | | | | | Net coke | Fluxes | Pig iron produced | Metalliferous materials consumed per ton of pig iron made (short tons) | | | | Coke and fluxes consumed per ton of pig iron (short tons) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Iron and manganiferous ores | | Agglomerates | Net ores and agglomerates[1] | Net scrap[2] | Miscellaneous[3] | Net total[4] | | | | Net ores and agglomerates[1] | Net scrap[2] | Miscellaneous[3] | Net total[4] | Net coke | Fluxes |
| | Domestic | Foreign | | | | | | | | | | | | | | |
| 1984: | | | | | | | | | | | | | | | | |
| Illinois | 1 | -- | 4,296 | 4,287 | 412 | 133 | 4,832 | 1,774 | 504 | 3,042 | 1.409 | 0.135 | 0.044 | 1.588 | 0.583 | 0.166 |
| Indiana and Michigan | 5 | 33 | 33,000 | 32,825 | 304 | 709 | 33,838 | 10,580 | 585 | 20,963 | 1.566 | .015 | .034 | 1.614 | .505 | .028 |
| Ohio | 30 | 46 | 13,775 | 13,740 | 435 | 424 | 14,599 | 5,651 | 922 | 9,593 | 1.432 | .045 | .044 | 1.522 | .589 | .096 |
| Pennsylvania | 109 | 1,227 | 10,551 | 11,793 | 446 | 92 | 12,331 | 4,167 | 554 | 7,603 | 1.551 | .059 | .012 | 1.622 | .548 | .073 |
| Alabama, Kentucky, Maryland | -- | 650 | 9,420 | 10,078 | 113 | 293 | 10,484 | 3,526 | 335 | 6,440 | 1.565 | .017 | .046 | 1.628 | .548 | .052 |
| Texas, Utah, West Virginia | 59 | 87 | 6,454 | 6,513 | 234 | 127 | 6,874 | 2,317 | 314 | 4,323 | 1.506 | .054 | .029 | 1.590 | .536 | .073 |
| Total[4] or average | 204 | 2,043 | 77,496 | 79,236 | 1,944 | 1,778 | 82,958 | 28,014 | [5]3,214 | 51,961 | 1.525 | .037 | .034 | 1.596 | .539 | .062 |
| 1985: | | | | | | | | | | | | | | | | |
| Illinois | -- | -- | 4,139 | 4,124 | 447 | 157 | 4,728 | 1,659 | 385 | 2,921 | 1.412 | .153 | .054 | 1.619 | .568 | .132 |
| Indiana and Michigan | 6 | 15 | 31,669 | 31,469 | 1,040 | 589 | 33,097 | 10,252 | 582 | 20,421 | 1.541 | .051 | .029 | 1.621 | .502 | .029 |
| Ohio | 2 | 1,372 | 13,410 | 14,687 | 308 | 592 | 15,587 | 5,229 | 969 | 9,259 | 1.586 | .033 | .064 | 1.683 | .565 | .105 |
| Pennsylvania | 48 | 1,031 | 8,949 | 9,961 | 293 | 333 | 10,586 | 3,563 | 581 | 6,473 | 1.539 | .045 | .051 | 1.635 | .550 | .090 |
| Alabama, Kentucky, Maryland | -- | 312 | 9,983 | 10,239 | 97 | 252 | 10,588 | 3,666 | 351 | 6,745 | 1.518 | .014 | .037 | 1.570 | .544 | .052 |
| Texas, Utah, West Virginia | 91 | 60 | 6,368 | 6,464 | 195 | 100 | 6,759 | 2,195 | 264 | 4,143 | 1.560 | .047 | .024 | 1.631 | .530 | .064 |
| Total[4] or average | 147 | 2,790 | 74,519 | 76,944 | 2,381 | 2,023 | 81,346 | 26,564 | [6]3,132 | 49,963 | 1.540 | .048 | .040 | 1.628 | .532 | .063 |

[1] Net ores and agglomerates equal ore plus agglomerates plus flue dust used minus flue dust recovered.

[2] Excludes home scrap produced at blast furnaces.

[3] Does not include recycled material.

[4] Data may not add to totals shown because of independent rounding.

[5] Fluxes consisted of the following: 1,595,000 tons of limestone, less than 500 tons of burnt lime, 1,444,000 tons of dolomite, and 173,000 tons of other fluxes, excluding 2,244,000 tons of limestone, 71,000 tons of burnt lime, 1,904,000 tons of dolomite, and 96,000 tons of other fluxes used in agglomerating production at or near steel plants and an unknown quantity used in making agglomerates at mines.

[6] Fluxes consisted of the following: 1,651,000 tons of limestone, 6,000 tons of burnt lime, 1,310,000 tons of dolomite, and 165,000 tons of other fluxes, excluding 2,417,000 tons of limestone, 15,000 tons of burnt lime, 1,663,000 tons of dolomite, and 28,000 tons of other fluxes used in agglomerating production at or near steel plants and an unknown quantity used in making agglomerates at mines.

## Table 6.—Number of blast furnaces in the United States, by State

| State | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | In blast[1] | Out of blast | Total | In blast[1] | Out of blast | Total |
| Alabama | 2 | 2 | 4 | 2 | 3 | 5 |
| Illinois | 4 | 1 | 5 | 4 | 2 | 6 |
| Indiana | 10 | 8 | 18 | 11 | 7 | 18 |
| Kentucky | 2 | -- | 2 | 2 | -- | 2 |
| Maryland | 2 | 2 | 4 | 3 | 1 | 4 |
| Michigan | 6 | 3 | 9 | 6 | 3 | 9 |
| Ohio | 11 | 10 | 21 | 11 | 8 | 19 |
| Pennsylvania | 8 | 14 | 22 | 9 | 11 | 20 |
| Texas | 1 | -- | 1 | 1 | -- | 1 |
| Utah | 2 | 1 | 3 | 2 | 1 | 3 |
| West Virginia | 3 | 1 | 4 | 3 | -- | 3 |
| Total | 51 | 42 | 93 | 54 | 36 | 90 |

[1] In blast for 180 days or more during the year.

## Table 7.—U.S. steel production, by type of furnace

(Thousand short tons)

| Year | Open-hearth | Basic oxygen converter | Electric | Total |
|---|---|---|---|---|
| 1981 | 13,452 | 73,231 | 34,145 | 120,828 |
| 1982 | 6,110 | 45,309 | 23,158 | 74,577 |
| 1983 | 5,951 | 52,050 | 26,615 | [1]84,615 |
| 1984 | 8,336 | 52,822 | 31,370 | 92,528 |
| 1985 | 6,428 | 51,885 | 29,946 | 88,259 |

[1] Data do not add to total shown because of independent rounding.

Source: American Iron and Steel Institute.

## Table 8.—Metalliferous materials consumed in steel furnaces[1] in the United States

(Thousand short tons)

| Year | Iron ore[2] | | Agglomerates[2] | | Pig iron | Ferroalloys[3] | Iron and steel scrap |
|---|---|---|---|---|---|---|---|
| | Domestic | Foreign | Domestic | Foreign | | | |
| 1981 | 27 | 207 | 43 | 34 | 71,284 | 1,663 | 63,195 |
| 1982 | 29 | 64 | 31 | 58 | 42,395 | 947 | 40,379 |
| 1983 | 9 | 96 | 75 | 33 | 48,300 | 1,063 | 45,280 |
| 1984 | 43 | 98 | 78 | 43 | 51,291 | [r]1,166 | 48,415 |
| 1985 | 54 | 91 | 79 | 29 | 49,257 | 1,088 | 49,889 |

[r] Revised.
[1] Basic oxygen converter, open-hearth, and electric furnaces.
[2] Consumed in integrated steel plants only.
[3] Includes ferromanganese, spiegeleisen, silicomanganese, manganese metal, ferrosilicon, ferrochromium, and ferromolybdenum. Includes ferroalloys added to steel outside the furnace.

## Table 9.—U.S. consumption of pig iron, by type of furnace or other use

| Type of furnace or other use | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Thousand short tons | Percent of total | Thousand short tons | Percent of total | Thousand short tons | Percent of total |
| Basic oxygen converter | 44,330 | 88.5 | 45,551 | 85.6 | 44,515 | 86.6 |
| Open-hearth | 3,918 | 7.8 | 5,720 | 10.7 | 4,737 | 9.2 |
| Electric | 341 | .7 | 368 | .7 | 503 | 1.0 |
| Cupola | 425 | .8 | 469 | .9 | 501 | 1.0 |
| Air and other furnaces[1] | 91 | .2 | 92 | .2 | 56 | .1 |
| Direct castings[2] | 965 | 1.9 | 1,002 | 1.9 | 1,100 | 2.1 |
| Total[3] | 50,070 | 100.0 | 53,202 | 100.0 | 51,411 | 100.0 |

[1] Includes vacuum-melting furnaces and miscellaneous melting processes.

[2] Castings made directly from blast furnace hot metal. Includes ingot molds and stools.

[3] Data may not add to totals shown because of independent rounding.

## Table 10.—U.S. consumption of pig iron,[1] by State

(Thousand short tons)

| State | 1984 | 1985 |
|---|---|---|
| Arkansas | 1 | -- |
| Connecticut | 5 | 6 |
| Georgia | 1 | 2 |
| Illinois | 2,884 | 2,702 |
| Indiana | 16,206 | 16,016 |
| Iowa | 30 | 42 |
| Kansas | 3 | 8 |
| Massachusetts | 16 | 24 |
| Michigan | 5,179 | 5,088 |
| Minnesota | 28 | 17 |
| Missouri | 6 | 4 |
| New Jersey | 2 | 1 |
| New York | 22 | 16 |
| Ohio | 10,309 | 9,700 |
| Oklahoma | 11 | W |
| Pennsylvania | 7,701 | 6,775 |
| Texas | 646 | 525 |
| Virginia | 14 | 13 |
| Wisconsin | 46 | 51 |
| Undistributed[2] | 10,092 | 10,422 |
| Total | 53,202 | [3]51,411 |

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."

[1] Includes molten pig iron used for ingot molds and direct castings.

[2] Includes Alabama, California, Colorado (1984), Delaware, Florida, Kentucky, Maine, Maryland, New Hampshire, North Carolina, Oregon, Rhode Island (1984), South Carolina, Tennessee, Utah, Washington, West Virginia, and item indicated by symbol W.

[3] Data do not add to total shown because of independent rounding.

## Table 11.—U.S. exports of major iron and steel products

| Product | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Steel mill products: | | | | | | |
| Ingots, blooms, billets, slabs, sheet bars | 102,756 | $27,638 | 73,536 | $19,165 | 89,708 | $28,000 |
| Wire rods | 6,346 | 7,246 | 8,744 | 10,187 | 4,922 | 8,047 |
| Structural shapes, 3 inches and over | 47,024 | 30,478 | 29,049 | 18,366 | 41,633 | 40,461 |
| Structural shapes, under 3 inches | 21,801 | 36,047 | 11,231 | 9,655 | 7,139 | 7,897 |
| Sheet piling | 2,097 | 11,527 | 3,355 | 2,655 | 628 | 466 |
| Plates | 101,982 | 61,875 | 88,185 | 54,162 | 82,988 | 57,784 |
| Rails and track accessories | 18,516 | 15,833 | 15,225 | 11,370 | 10,937 | 10,844 |
| Wheels and axles | 1,558 | 9,040 | 3,854 | 13,377 | 2,493 | 14,875 |
| Concrete reinforcing bars | 34,528 | 9,340 | 9,889 | 4,678 | 7,409 | 3,553 |
| Bars, carbon, hot-rolled | 36,592 | 17,759 | 32,162 | 16,377 | 27,577 | 11,842 |
| Bars, alloy, hot-rolled | 53,992 | 41,626 | 49,969 | 39,773 | 34,871 | 37,298 |
| Bars, cold-finished | 21,567 | 24,954 | 28,125 | 24,796 | 20,854 | 28,182 |
| Hollow drill steel | 1,378 | 3,279 | 2,123 | 2,920 | 1,062 | 1,891 |
| Pipe and tubing | 257,967 | 404,319 | 207,428 | 325,800 | 199,258 | 285,182 |
| Wire | 20,349 | 37,689 | 19,440 | 37,747 | 18,758 | 31,215 |
| Nails, brads, spikes, staples | 6,916 | 24,326 | 7,161 | 24,199 | 5,445 | 21,670 |
| Blackplate | 60,929 | 13,704 | 38,781 | 9,779 | 32,754 | 7,704 |
| Tinplate and terneplate | 188,628 | 83,826 | 138,764 | 70,149 | 141,729 | 64,463 |
| Sheets, hot-rolled | 42,544 | 32,934 | 51,580 | 39,220 | 56,696 | 35,429 |
| Sheets, cold-rolled | 50,431 | 47,126 | 51,202 | 46,236 | 46,465 | 47,968 |
| Strip, hot-rolled | 16,428 | 16,308 | 11,563 | 14,254 | 12,482 | 13,742 |
| Strip, cold-rolled | 26,152 | 42,255 | 26,182 | 46,696 | 23,827 | 41,073 |
| Plates, sheets, strip, galvanized, coated or clad | 78,142 | 55,665 | 69,736 | 62,450 | 60,319 | 55,493 |
| Total | 1,198,623 | 1,054,794 | 977,284 | 904,011 | 929,954 | [1]855,078 |
| Other steel products: | | | | | | |
| Plates and sheets, fabricated | 21,990 | 39,922 | 11,371 | 22,965 | 18,677 | 27,214 |
| Structural shapes, fabricated | 65,803 | 133,037 | 86,854 | 141,849 | 46,770 | 93,396 |
| Architectural and ornamental work | 3,643 | 15,178 | 2,207 | 9,186 | 1,765 | 8,174 |
| Sashes and frames | 9,197 | 38,069 | 8,986 | 31,894 | 6,815 | 20,839 |
| Pipe and tube fittings | 22,831 | 141,646 | 11,426 | 98,915 | 16,362 | 126,336 |
| Pipe and tubing, coated or lined | 13,025 | 17,533 | 7,778 | 12,535 | 5,472 | 8,010 |
| Bolts and nuts | 72,913 | 106,242 | 86,897 | 127,017 | 58,944 | 106,094 |
| Forgings | 33,048 | 55,132 | 41,739 | 63,515 | 46,269 | 68,444 |
| Cast-steel rolls | 977 | 2,347 | 1,438 | 2,415 | 1,471 | 2,389 |
| Railway track material | 3,215 | 4,788 | 2,550 | 3,661 | 2,848 | 5,276 |
| Total | 246,642 | 553,894 | 261,246 | 513,942 | [1]200,387 | 465,672 |
| Iron products: | | | | | | |
| Cast-iron pipes, tubes, fittings | 85,513 | 128,523 | 51,682 | 99,252 | 41,523 | 64,236 |
| Iron castings | 58,344 | 45,866 | 122,375 | 110,084 | 94,419 | 90,994 |
| Total | 143,857 | 174,389 | 174,057 | 209,336 | 135,942 | 155,230 |
| Grand total | 1,589,122 | 1,783,077 | 1,412,587 | 1,627,289 | 1,266,283 | 1,475,980 |

[1] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

## Table 12.—U.S. imports for consumption of pig iron, by country

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Belgium-Luxembourg | 915 | $129 | -- | -- | -- | -- |
| Brazil | 135,955 | 14,413 | 421,176 | $43,703 | 130,762 | $13,772 |
| Canada | 94,802 | 16,004 | 171,708 | 29,638 | 166,291 | 29,920 |
| China | -- | -- | -- | -- | 1,968 | 330 |
| France | 772 | 101 | 1,704 | 253 | 7,241 | 1,219 |
| South Africa, Republic of | 9,650 | 1,259 | 31,489 | 4,593 | 30,504 | 4,936 |
| Venezuela | -- | -- | 54,274 | 3,815 | -- | -- |
| Other | 20 | 10 | 22,004 | 1,983 | 1,492 | 442 |
| Total | 242,114 | [1]31,917 | 702,355 | 83,985 | 338,258 | 50,619 |

[1] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

## Table 13.—U.S. imports for consumption of major iron and steel products

| Product | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Steel mill products: | | | | | | |
| Ingots, blooms, billets, slabs, sheet bars | 822,483 | $176,621 | 1,515,734 | $332,664 | 1,878,953 | $385,462 |
| Wire rods | 1,188,918 | 392,317 | 1,594,437 | 540,315 | 1,479,749 | 501,994 |
| Structural shapes, 3 inches and over | 1,489,226 | 425,557 | 2,075,027 | 587,961 | 2,019,245 | 580,305 |
| Structural shapes, under 3 inches | 88,288 | 29,298 | 174,787 | 60,846 | 140,317 | 53,507 |
| Sheet piling | 69,050 | 26,744 | 80,709 | 30,862 | 102,790 | 37,837 |
| Plates | 1,393,378 | 358,945 | 1,880,297 | 539,927 | 2,303,682 | 628,335 |
| Rails and track accessories | 168,933 | 56,528 | 350,300 | 113,724 | 358,442 | 127,906 |
| Wheels and axles | 6,500 | 7,030 | 23,591 | 18,184 | 23,604 | 19,638 |
| Concrete reinforcing bars | 208,304 | 39,126 | 434,147 | 87,581 | 409,612 | 88,353 |
| Bars, carbon, hot-rolled | 322,518 | 109,504 | 540,302 | 184,926 | 445,001 | 152,544 |
| Bars, alloy, hot-rolled | 139,806 | 87,275 | 216,421 | 118,633 | 207,427 | 112,279 |
| Bars, cold-finished | 204,575 | 160,887 | 338,754 | 213,840 | 326,395 | 213,158 |
| Hollow drill steel | -- | -- | 1,811 | 2,310 | 1,260 | 1,383 |
| Welded pipe and tubing | 1,728,716 | 595,175 | 2,753,108 | 1,051,932 | 2,529,895 | 1,028,470 |
| Other pipe and tubing | 1,124,266 | 650,002 | 2,676,358 | 1,394,148 | 1,942,051 | 1,173,810 |
| Wire | 478,776 | 316,761 | 702,493 | 472,053 | 629,086 | 428,856 |
| Wire nails | 374,039 | 188,544 | 458,326 | 235,270 | 403,522 | 199,126 |
| Wire fencing, galvanized | 10,762 | 6,991 | [r]12,011 | [r]7,459 | 25,311 | 16,915 |
| Blackplate | 170,420 | 66,939 | 278,003 | 116,068 | 241,375 | 99,928 |
| Tinplate and terneplate | 293,819 | 168,413 | 373,277 | 203,147 | 419,242 | 222,114 |
| Sheets, hot-rolled | 2,030,684 | 545,735 | 2,690,721 | 782,510 | 2,433,705 | 708,727 |
| Sheets, cold-rolled | 2,425,167 | 886,228 | 3,672,456 | 1,499,599 | 2,803,532 | 1,208,379 |
| Sheets, coated (including galvanized) | 2,059,275 | 863,471 | 2,899,825 | 1,319,928 | 2,621,340 | 1,226,192 |
| Strip, carbon, hot-rolled | 32,530 | 11,491 | 79,592 | 25,373 | 62,154 | 19,353 |
| Strip, carbon, cold-rolled | 66,090 | 55,159 | 145,333 | 95,717 | 216,458 | 127,200 |
| Strip, alloy, hot- or cold-rolled (including stainless) | 27,798 | 47,447 | 51,604 | 86,441 | 67,849 | 105,585 |
| Plates, sheets, strip, electrolytically coated (other than with tin, lead, or zinc) | 110,067 | 61,448 | 149,624 | 79,656 | 186,485 | 98,291 |
| Total | 17,034,388 | 6,333,636 | [r]26,169,048 | [r]10,201,074 | 24,278,482 | 9,565,642 |
| Other steel products: | | | | | | |
| Plates, sheets, strip, fabricated | 5,536 | 4,430 | 13,085 | 11,805 | 36,157 | 16,578 |
| Structural shapes, fabricated | 206,296 | 155,308 | 235,950 | 136,717 | 285,169 | 271,542 |
| Pipe fittings | 71,161 | 92,146 | 105,095 | 136,475 | 118,328 | 176,135 |
| Rigid conduit | 282 | 2,187 | 373 | 15,826 | 17,650 | 11,955 |
| Bale ties made from strip | 643 | 546 | [r]940 | [r]642 | 812 | 634 |
| Nails, brads, spikes, staples, tacks, not of wire | 40,670 | 46,977 | 48,662 | 61,217 | 45,801 | 60,298 |
| Bolts, nuts, rivets, washers, etc | 450,707 | 473,157 | 684,761 | 753,707 | 638,314 | 724,509 |
| Forgings | 28,800 | 20,730 | 57,267 | 38,997 | 68,915 | 47,270 |
| Total | 804,095 | 795,481 | [r]1,146,133 | [r]1,155,386 | 1,211,146 | 1,308,921 |
| Iron products: | | | | | | |
| Cast-iron pipes, tubes, fittings | 30,629 | 32,155 | 40,471 | 42,211 | 78,395 | 59,455 |
| Iron castings | 94,742 | 76,693 | 132,078 | 96,675 | 139,313 | 85,088 |
| Total | 125,371 | 108,848 | 172,549 | 138,886 | 217,708 | 144,543 |
| Grand total | 17,963,854 | 7,237,965 | 27,487,730 | 11,495,346 | 25,707,336 | 11,019,106 |

[r] Revised.

Source: Bureau of the Census.

## Table 14.—Pig iron: World production, by country[1]

(Thousand short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria | 989 | [r]1,209 | 1,213 | [r] [e]1,210 | 1,210 |
| Argentina[3] | 1,896 | 2,090 | 2,052 | 1,983 | [4]2,557 |
| Australia | 7,529 | 6,565 | 5,561 | 5,874 | [4]6,173 |
| Austria | 3,832 | 3,434 | 3,660 | 4,128 | [4]4,117 |
| Belgium | 10,724 | 8,638 | 8,849 | 9,886 | [4]9,611 |
| Brazil[3] | 11,901 | 11,935 | 14,269 | 18,960 | [4]20,911 |
| Bulgaria | 1,667 | 1,717 | 1,789 | 1,739 | [4]1,876 |
| Burma | 4 | 14 | 17 | 9 | 13 |
| Canada | 10,740 | 8,818 | 9,443 | 10,629 | [4]10,646 |
| Chile | 642 | 500 | 595 | 654 | [4]634 |
| China | 37,666 | 39,171 | 41,204 | 44,070 | 48,100 |
| Colombia | 257 | 271 | 266 | 299 | [4]271 |
| Czechoslovakia | 10,354 | 10,500 | 10,434 | 10,539 | 10,500 |
| Egypt | [e]240 | 125 | 216 | 248 | 250 |
| Finland | 2,180 | 2,157 | 2,092 | 2,242 | 2,000 |
| France | 19,035 | 16,569 | 15,274 | 16,578 | [4]17,004 |
| German Democratic Republic[5] | 2,691 | 2,369 | 2,433 | 2,598 | 2,800 |
| Germany, Federal Republic of | 35,137 | 30,447 | 29,319 | 33,293 | [4]34,719 |
| Greece | [r]48 | [r]121 | 152 | 152 | 150 |
| Hungary | 2,417 | 2,404 | 2,256 | 2,310 | [4]2,309 |
| India | 10,443 | 10,582 | 10,016 | 10,342 | [4]10,841 |
| Iran[e] | 600 | 700 | 800 | 800 | 800 |
| Italy | 13,514 | 12,717 | 11,399 | 12,818 | [4]12,851 |
| Japan | 88,238 | 85,603 | 80,398 | 88,629 | [4]88,812 |
| Korea, North[e] | 5,500 | 5,800 | 6,100 | 6,300 | 6,400 |
| Korea, Republic of | 8,739 | 9,309 | 8,845 | 9,660 | 9,700 |
| Luxembourg[5] | 3,185 | 2,852 | 2,553 | 3,051 | [4]3,037 |
| Mexico[3] | 6,011 | 5,625 | 5,549 | 5,895 | [4]5,483 |
| Morocco[e] | 13 | 13 | 17 | 17 | 17 |
| Netherlands | 5,071 | 3,987 | 3,800 | 5,430 | [4]5,313 |
| New Zealand[e] [3] | 165 | 165 | 170 | 190 | 190 |
| Norway | [r]647 | [r]503 | 623 | 631 | 670 |
| Pakistan[e] | [r]200 | [r]470 | [r]520 | [r]624 | [4]885 |
| Peru[3] | 266 | 225 | 154 | 68 | 235 |
| Poland | 10,307 | 9,395 | 10,710 | 11,002 | 11,000 |
| Portugal | 452 | 237 | 391 | 411 | [4]456 |
| Romania | 9,763 | 9,521 | 9,028 | [e]8,900 | 8,900 |
| South Africa, Republic of | 8,119 | 7,454 | 5,746 | 6,013 | [4]7,247 |
| Spain | 7,080 | 6,604 | 5,950 | 5,884 | [4]6,037 |
| Sweden[3] | 2,131 | 2,076 | 2,328 | 2,561 | 2,650 |
| Switzerland | [r]36 | [r]11 | 11 | 60 | 55 |
| Taiwan | 1,776 | 2,971 | 3,764 | 3,704 | 3,750 |
| Thailand | 11 | 7 | ([6]) | -- | -- |
| Trinidad and Tobago (sponge iron) | 198 | 261 | 313 | 263 | 230 |
| Tunisia | [r]174 | [r]107 | 162 | 165 | 165 |
| Turkey | [r]2,260 | [r]2,396 | 2,997 | 3,161 | 3,245 |
| U.S.S.R | 118,141 | 116,955 | 120,923 | 122,238 | 121,000 |
| United Kingdom | 10,439 | 9,179 | 10,447 | 10,458 | 11,600 |
| United States | 73,755 | 43,342 | 48,770 | 51,961 | [4]49,963 |
| Venezuela[3] | 2,458 | 2,598 | 2,476 | 3,511 | 3,300 |
| Yugoslavia | 3,105 | 2,980 | 3,136 | 3,147 | [4]3,439 |
| Zimbabwe | [e]440 | [e]300 | 1,021 | 1,022 | 1,100 |
| Total | [r]553,186 | [r]503,999 | 510,211 | 546,317 | 555,222 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Table excludes ferroalloy production except where otherwise noted. Table includes data available through June 24, 1986.

[2] In addition to the countries listed, Vietnam and Zaire have facilities to produce pig iron and may have produced limited quantities during 1981-85, but output is not reported and available general information is not adequate to permit formulation of reliable estimates of output levels.

[3] Includes sponge iron output.

[4] Reported figure.

[5] Includes blast furnace ferroalloys.

[6] Less than 1/2 unit.

## Table 15.—Raw steel:[1] World production, by country[2]

(Thousand short tons)

| Country[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria[e] | [4]575 | 630 | 660 | 770 | 830 |
| Angola[e] | 11 | 11 | 11 | 11 | 11 |
| Argentina | 2,784 | 3,211 | 3,244 | 2,918 | [4]3,242 |
| Australia | 8,416 | 7,023 | 6,200 | 6,943 | 7,290 |
| Austria | 5,132 | 4,694 | 4,862 | 5,368 | 5,200 |
| Bangladesh[5] | 153 | 120 | 52 | 80 | [4]111 |
| Belgium | 13,645 | 10,931 | 11,196 | 12,459 | [4]11,788 |
| Brazil | 14,584 | [r]14,330 | 16,160 | 20,267 | [4]22,549 |
| Bulgaria | 2,738 | 2,848 | 3,121 | 3,172 | [4]3,225 |
| Canada | 16,326 | 12,965 | 14,140 | 16,220 | 16,500 |
| Chile | 710 | 542 | 681 | 763 | [4]751 |
| China | 39,242 | 40,962 | 44,040 | 47,800 | 51,500 |
| Colombia | 443 | 466 | 531 | 550 | [4]584 |
| Cuba | 364 | 332 | 401 | 373 | 410 |
| Czechoslovakia | 16,832 | 16,526 | 16,561 | 16,348 | [4]16,574 |
| Denmark | 675 | 617 | 543 | 604 | 580 |
| Ecuador | 31 | 31 | 25 | 20 | [4]20 |
| Egypt | [r]243 | [r]125 | 216 | 248 | 250 |
| El Salvador[e] | 11 | 8 | 17 | [r]12 | 11 |
| Finland | 2,676 | 2,661 | 2,663 | 2,901 | 2,750 |
| France | 23,433 | 20,300 | 19,426 | 20,944 | [4]20,759 |
| German Democratic Republic | 8,231 | 7,902 | 7,958 | 8,348 | [4]8,708 |
| Germany, Federal Republic of | 45,867 | 39,551 | 39,384 | 43,419 | [4]44,644 |
| Greece | 1,002 | [r]1,028 | 946 | 987 | [4]1,086 |
| Hong Kong[e] | 130 | 130 | 130 | 130 | 130 |
| Hungary | 4,016 | 4,081 | 3,986 | 4,134 | [4]4,020 |
| India[6] | 11,442 | 11,811 | 11,359 | 11,402 | 11,970 |
| Indonesia | 551 | 551 | 882 | [e]1,100 | 1,500 |
| Iran[e] | 1,300 | 1,300 | 1,500 | 1,300 | 1,300 |
| Iraq[e] | 50 | 50 | (7) | (7) | -- |
| Ireland | 35 | 61 | 150 | [r] [e]170 | 220 |
| Israel | [r]132 | [r]132 | 165 | [e]220 | 170 |
| Italy | 27,312 | 26,434 | 23,891 | 26,484 | [4]26.173 |
| Japan | 112,078 | 109,733 | 107,121 | 116,389 | [4]116,052 |
| Jordan | 149 | 154 | [e]150 | [e]150 | 150 |
| Kenya[e] | 11 | 11 | 11 | 11 | 11 |
| Korea, North[e] | 6,100 | 6,400 | 6,700 | 7,200 | 7,200 |
| Korea, Republic of | 11,854 | 12,955 | 13,134 | 14,366 | 14,900 |
| Luxembourg | 4,178 | 3,869 | 3,631 | 4,395 | [4]4,349 |
| Malaysia[e] | 230 | 230 | 390 | 390 | 390 |
| Mexico | 8,447 | 7,778 | 7,692 | 8,277 | [4]8,015 |
| Morocco[e] | 7 | 7 | 7 | 7 | 7 |
| Netherlands | 6,032 | 4,791 | 4,935 | 6,326 | [4]6,063 |
| New Zealand | 255 | 278 | 257 | 302 | 250 |
| Nigeria[e] | 17 | 110 | 150 | [r]200 | [4]280 |
| Norway | 935 | 847 | 987 | 1,009 | 1,000 |
| Pakistan[e] | 390 | 390 | 600 | [r]670 | 770 |
| Peru | 401 | 302 | 330 | 377 | [4]453 |
| Philippines | 386 | 386 | 220 | [e]280 | 220 |
| Poland | 17,327 | 16,309 | 17,897 | 18,224 | [4]17,747 |
| Portugal | 607 | 556 | 734 | 757 | [4]731 |
| Qatar | 499 | 524 | 526 | [e]538 | 540 |
| Romania | 14,358 | 14,391 | 13,881 | 15,914 | [4]15,212 |
| Saudi Arabia | [e]80 | [e]77 | 303 | 928 | 940 |
| Singapore[e] | 386 | 386 | 386 | 390 | 390 |
| South Africa, Republic of | 9,925 | 9,117 | 7,926 | 8,628 | 8,300 |
| Spain | 14,233 | 14,506 | 14,034 | 14,864 | [4]15,691 |
| Sweden | [r]4,168 | [r]4,339 | 4,537 | 5,186 | 5,200 |
| Switzerland | 1,065 | 1,047 | 920 | 1,078 | 1,100 |
| Syria[e] | 120 | [4]109 | 90 | [r]76 | 76 |
| Taiwan | 3,465 | 4,495 | 5,530 | [e]5,500 | 5,500 |
| Thailand | 331 | 344 | 269 | [e]280 | 280 |
| Trinidad and Tobago | 58 | [r]197 | 231 | 219 | [4]184 |
| Tunisia[e] | [r]176 | [r]110 | [r]165 | [r]165 | 165 |
| Turkey | [r]2,673 | [r]3,134 | 4,227 | 4,729 | [4]5,469 |
| U.S.S.R | 163,632 | 162,221 | 168,118 | 170,018 | 171.000 |
| United Kingdom | 17,170 | 15,106 | 16,519 | 16,668 | [4]17,331 |
| United States | 120,828 | 74,577 | 84,615 | 92,528 | [4]88,259 |
| Uruguay | 17 | 31 | 51 | 53 | 50 |

See footnotes at end of table.

## Table 15.—Raw steel:[1] World production, by country[2] —Continued

(Thousand short tons)

| Country[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Venezuela[6] | 2,003 | 2,531 | 2,820 | 3,241 | 3,500 |
| Vietnam[e] | 120 | 130 | 110 | 110 | 110 |
| Yugoslavia | 4,383 | 4,244 | 4,558 | 4,669 | [4]4,938 |
| Zimbabwe | 762 | 582 | 741 | 431 | 440 |
| Total | [r]778,948 | [r]709,668 | 730,604 | 782,008 | 788,119 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Steel formed in first solid state after melting, suitable for further processing or sale; for some countries, includes material reported as "liquid steel," presumably measured in the molten state prior to cooling in any specific form.

[2]Table includes data available through June 24, 1986.

[3]In addition to the countries listed, Ghana, Libya, and Mozambique are known to have steelmaking plants, but available data are insufficient to make reliable production estimates. Burma reportedly has a remelt capacity of 40,000 tons; however, plant output, if any, is not known.

[4]Reported figure.

[5]Data are for year ending June 30 of that stated.

[6]Includes steel castings.

[7]Revised to zero.

# Iron and Steel Scrap

## By Franklin D. Cooper[1]

Brokers, dealers, and other outside sources supplied domestic consumers with 37.4 million tons[2] of all types of ferrous scrap at a delivered value of approximately $2.94 billion, while exporting 9.95 million tons valued at $918 million. In 1984, domestic consumers received 34.3 million tons at a delivered value of approximately $2.82 billion, while exports totaled 9.5 million tons valued at $918 million.

**Domestic Data Coverage.**—Domestic production data for ferrous scrap are developed by the Bureau of Mines from voluntary monthly or annual surveys of U.S. operations. Of the operations to which a survey request was sent, 76% responded, representing an estimated 80% of the total consumption shown in table 2 for three types of scrap consumers. Consumption for the nonrespondents was estimated using prior reports adjusted by industry trends. An estimation error is also contained in the difference between the reported total consumption of purchased and home scrap and the sum of scrap receipts plus home scrap production, less scrap shipments, and adjustments for stock changes. For scrap consumption data shown in table 2, this difference amounted to 1% for the manufacturers of pig iron and raw steel and castings, 0.3% for the manufacturers of steel castings, and 3% for iron foundries and miscellaneous users.

**Table 1.—Salient U.S. iron and steel scrap and pig iron statistics**

(Thousand short tons and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Stocks, Dec. 31: | | | | | |
| Scrap at consumer plants | 8,118 | 6,418 | 5,807 | 5,261 | 5,104 |
| Pig iron at consumer and supplier plants | 859 | 622 | 345 | 304 | 266 |
| Total | 8,977 | 7,040 | 6,152 | 5,565 | 5,370 |
| Consumption: | | | | | |
| Scrap | 85,097 | 56,386 | 61,782 | 65,702 | 70,493 |
| Pig iron | 75,040 | 44,409 | 50,070 | 53,202 | 51,411 |
| Exports: | | | | | |
| Scrap (excludes rerolling material and ships, boats, and other vessels for scrapping) | 6,415 | 6,804 | 7,520 | 9,498 | 9,950 |
| Value | $638,644 | $610,302 | $636,723 | $917,981 | $918,186 |
| Imports for consumption: | | | | | |
| Scrap (includes tinplate and terneplate) | 556 | 468 | 641 | 572 | 601 |
| Value | $62,126 | $37,572 | $48,219 | $46,946 | $45,620 |

**Legislation and Government Programs.**—On July 12, 1985, the President signed compromise legislation (S. 883) to reauthorize the Export Administration Act of 1979 and for other purposes. This Public Law 99-64 included limited contract sanctity, clarified the foreign availability test, and required the President to consult with an affected industry before imposing export policy controls.

Findings of the U.S. International Trade Commission (ITC), published in May 1985, indicated that imports of slab steel in the 1979-83 period had no significant impact on the U.S. ferrous scrap industry.

Rhode Island's tax administrator determined that a scrap metal processor producing tangible personal property for sale was exempt from the State's sales and use taxes on new equipment purchased and that its investment in processing equipment was classed as an investment tax credit.

Massachusetts was the 50th State to classify a scrap metal processor as a manufacturing business.

## AVAILABLE SUPPLY, CONSUMPTION, AND STOCKS

In expectation of a severe winter, steel producers built up their stocks and then drastically reduced purchases in early spring. Scrap processors in the Midwest reluctantly agreed to overnight delivery to some purchasers who maintained small stocks. Scrap processors in the South sold scrap at bargain prices to maintain some cash flow. An oversupply of ferrous scrap in the Pittsburgh area was further increased by the fabrication of domestic-made and imported steel products. LTV Steel Co.'s Pittsburgh Works with two electric arc furnaces (EAF) was the principal consumer at a maximum 50,000- to 60,000-ton-per-month demand. In August, scrap demand for the Pittsburgh area foundries was at such a low level that it was difficult to set prices on foundry scrap grades. Scrap demand was further decreased in the area because LTV no longer made steel in its Aliquippa Works and Wheeling-Pittsburgh Steel Corp.'s plants were strikebound for 2 months.

Raw steel production was 88.3 million tons compared with 92.5 million tons in 1984. Raw steel capacity utilization was 66.1% in 1985 compared with 68.4% in 1984.

Steel mills accounted for 71.9% of all scrap received from brokers, dealers, and other outside sources; steel foundries received 4.1%, and iron castings producers and miscellaneous users received 24.0%.

The apparent consumption of scrap, in million tons, comprised 38.8 net receipts (total receipts minus shipments), 30.5 home scrap, 0.6 imports, and 0.2 withdrawals from stocks for a total of 70.1.

The 1984-85 status of U.S. manufacturing sectors that were major consumers of iron and steel products was as follows:

*Appliances.*—In 1985, 41.8 million units were shipped, 17% more than in 1984.

*Automobiles.*—In 1985, 8.2 million units were made in the United States, 5.1% more than in 1984. In the first 5 months of 1985, 169,600 recreational vehicles were shipped to dealers, 9.4% less than in 1984, and in the first 6 months of 1985, 39,900 recreational homes were shipped to dealers, 16% less than in 1984.

*Castings, iron.*—Shipments totaled 10.1 million tons in 1985 compared with 10.9 million tons in 1984.

*Castings, steel.*—Shipments totaled 889,000 tons in 1985 compared with 940,000 tons in 1984.

*Construction equipment.*—The value of shipments in 1985 totaled $4.2 billion compared with $4.0 billion in 1984.

*Farm, wheeled tractors.*—Units sold in 1985 totaled 120,000 compared with 110,000 in 1984.

*Housing starts.*—Starts in 1985 totaled 1.74 million tons compared with 1.75 million in 1984.

*Materials handling.*—The value of shipments in 1985 was $4.4 billion compared with $4.0 billion in 1984.

*Mining equipment.*—Sales were $155 million in 1985 and $125 million in 1984.

*Service centers, steel.*—Shipments to service centers were 21.0 million tons in 1985 and 20.9 million tons in 1984.

*Shipbuilding.*—Contracts in 1985 totaled $753 million for nine ships for the Armed Forces and five noncombat ships. The total for 1984 contracts was $530 million.

*Steel.*—Shipments of all grades of finished steel were 72.7 million tons in 1985 and 73.7 million tons in 1984.

*Tubular goods.*—Shipments were 1.5 million tons in 1985 and 1.2 million tons in 1984. These tonnages exclude oil country products.

News of acquisitions included the following: Steelmet Inc., Pittsburgh, PA, was purchased by ELG Haniel Metals Corp., a wholly owned subsidiary of Haniel GmbH, Duisburg, Federal Republic of Germany; Purdy Metals Corp. sold its Los Angeles, CA, scrapyard to Hugo Neu, a major scrap exporter situated on nearby Terminal Island; Miller Compressing Co. bought most of the assets of Afram Bros. Co., Milwaukee, WI; the Union Corp., Verona, PA, sold the operating assets of its Jacobsen Metal Co., Chesapeake, VA, division to some private investors; and Addlestone International

Corp., Charleston, SC, purchased Associated Iron & Metal Co., Jacksonville, FL.

New ventures included the following: Orange County Steel Salvage Inc. opened an export yard on Terminal Island, CA, featuring the Ro-Con method of loading that included containers and bulk shipments so that 20,000 tons of scrap could be loaded aboard a vessel in 2 days; Schiabo-Chatham Co., Savannah, GA, and Southern Scrap Material Co. Ltd., Baton Rouge, LA, created a new venture for purchasing, processing, and marketing stainless steel scrap in the gulf region; and Steelmet opened a trading office in St. Louis, MO, to handle stainless and nickel alloy scrap sales.

Scrapyard closings included the permanent termination in October 1985 of the export yard of Schiavone & Sons Inc., Boston, MA, and the processing facilities of World Trade Options, Spring Valley, NY.

Phibro Bros. (United States) in August severed its trade connections with the Republic of South Africa, and in late October, announced that its subsidiary Philipp Bros. would withdraw from steel, bulk ferroalloys, and ferrous scrap trading. Resulting dismissals will affect 600 of its 1,400 employees.

Some miscellaneous happenings relating to ferrous scrap were as follows: The Public Service of Indiana in June auctioned portions of $700 million worth of steel and equipment intended for a nuclear plant that was canceled in 1984; General Motors Corp.'s plan to take its automobile bundle scrap off the open market was postponed for the second time in November; Schnitzer Steel Products Co., Oakland, CA, was selected to be the exclusive scrap supplier for Judson Steel Corp., Emeryville, CA; and Lindemann Recycling Equipment Inc., a subsidiary of Lindemann Machinefabric GmbH of Dusseldorf, Federal Republic of Germany, established its U.S. headquarters in New York City.

Ferrous scrap in stockpiles of domestic consumers totaled 5,104,000 tons at yearend, down 157,000 tons from the 5,261,000 tons at yearend 1984. Stocks held by steel manufacturers continued a recurring annual decline, while stocks held by makers of ferrous castings increased significantly in 1985.

The U.S. ferrous scrap industry's annual processing capability in 1984 was 130 million tons, 18% more than that of 1974, according to a report by the Battelle Columbus Laboratories for the Metal Scrap Research and Education Foundation (MSREF). The replacement value of the industry's capital investment increased to $2.3 billion, 183% more than that of 1974. Land represented a $636 million investment, and buildings, $481 million. The cost of a greenfield scrap processing yard was $1.5 million to $2.0 million. In 1984, there were 1,407 processing plants in operation compared with 1,330 in 1974. The number of plants in the 30,000- to 60,000-ton-per-year range was 275, up from 152 such plants in 1974. Collectively, the East North-Central and Northeast census regions accounted for 50% of the total U.S. plants and 63% of the total tonnage processed.

According to the Battelle report, in 1984, 800 balers processed 8.9 million tons; 770 guillotine shears processed 11.2 million tons; and 200 shredders processed 11.2 million tons. Ferrous scrap processors operated 36,000 pieces of equipment, of which balers, guillotine shears, and alligator shears were the predominant types; shredders and briquetters had the largest relative growth in the 1974-84 period. Shears, balers, and shredders of recent vintage required less power input and had a longer life than similar equipment placed in operation 10 to 20 years earlier. The installed cost of a guillotine shear ranged from $450,000 to $800,000, and a large-capacity baler cost up to $2 million.

A growing trend for processing the total products from an automobile shredder using water instead of air to separate the nonmetallic constituents. The wet system required less power and reduced air pollution.

Scrap processing equipment, in new or redesigned configurations, offered by the United States and foreign manufacturers included balers capable of higher productivity while making higher density bundles from the Harris Press and Shear Co., Cordele, GA; Al-jon's 990 four-wheel drive hydrostatic loader; and Caterpillar Tractor Co.'s integrated toolcarrier wheel loader with power takeoff for use with a variety of small equipment in scrapyards. Shears available included La Bounty Model MSD-22, capable of processing subway cars in an as-received condition; ECON's Model 210-P portable guillotine shear; and Harris energy-efficient Model BSH-22-883 shear. The joint use of a 245 Hydraulic Excavator teamed with a La Bounty shear could process one railroad car per hour into No. 1 heavy melting scrap, and Allied-Gator Co.'s mobile shear was capable of a shearing force up to 1,600 tons.

Foreign-made shears included six basic models from Dudley Shearing Machine Manufacturing Co. Ltd., Stoke-on-Trent, United Kingdom; shears from J. McIntyre (Machinery) Ltd., Nottingham, United Kingdom; and a shear marketed by the NEW DJ Press Co., a division of Wendt Manufacturing Corp., North Tonawanda, NY, made by Thyssen Henschel of the Federal Republic of Germany, the use of which did not need feed scrap presorting. Southern Scrap, a large tonnage processor in New Orleans, LA, bought a Lindemann LU-810 shear made in the Federal Republic of Germany. The shear was put into operation in late 1985.

The Fujiar Newell shredder, introduced into Japan in 1980, now has the dominant share of new shredder sales in Japan. The shredder is made by Fujican Manufacturing Co. under license from Newell Industries Inc.

Proler International Corp., Houston, TX, operated nine shredders either in a joint venture with Prolerized Schiabo Neu Co. or by Proler alone.

Cholmondeley Industrial Associates Inc., Cincinnati, OH, was selected by Lindemann Recycling to represent its processing equipment in Kentucky, Tennessee, and parts of Indiana, Ohio, and West Virginia. Harris became the sole agent in the United Kingdom for Lollini S.p.A. of Italy, and Lollini will be Harris' agent in Italy for Harris' equipment, excluding balers.

Analyzers for a wide range of scrap metals included the 3600 Mobil Metal Analyzer of Applied Research Laboratories; the Clandon Portable Metascope from Clandon Scientific Ltd., Aldershot, HANTS, United Kingdom, G0125QR; the X-Met 840, a handheld, portable, microprocessor-based, multielement X-ray fluorescent analyzer by Columbia Scientific Industries Corp.; a readout system, called Spectrographix 16, from the Labtest Equipment Co.; Texas Nuclear's 9266 Alloy Analyzer; and Walker Scientifics Inc.'s Alloy Thermo-Sorter Model ATS-6044.

Activities of ferrous-scrap-related foundations and associations are noted. The Executive Director of the Institute of Scrap Iron and Steel (ISIS) testified on March 12 before the ITC that imports of semifinished steel and slabs threatened the domestic scrap industry. ISIS published a booklet relating to insurance coverage for scrap processors. ISIS' members in the Buffalo, NY, area and ISIS' national office stopped the Buffalo City Council's attempt to classify scrap metal processing operations as junkyards. ISIS approved the provisions of the Export Administration Act of 1985, and ISIS issued a general information, updated and revised, folder entitled "Mines Above Ground." MSREF, the research arm of ISIS, updated the original 1975 study of the U.S. ferrous scrap industry's processing capability. The study's results showed current processing capability to be 130 million tons per year. A detailed listing and count of the major types of equipment, plant count, and net capacity of equipment installed or on order were published in the fall 1985 issue of the ISIS "Phoenix Quarterly." The National Association of Recycling Industries Inc. (NARI), in May, postponed the establishment of an association to negotiate favorable freight rates. NARI opposed proposed legislation in Rhode Island to make recycling mandatory.

Safety conditions received increasing attention in the processing and use of ferrous scrap. J. J. Keller and Associates Inc., Neenah, WI, introduced its new Hazardous Material Incident Kit designed to provide instructions and material to respond to a hazardous release of contaminants from ferrous scrap. The Environmental Protection Agency (EPA) determined in February that scrapyard shredder residue contaminated by sodium azide from airbag canisters was not hazardous. To call attention to hazardous materials, ISIS started an advertising campaign directed to State government officials. A full-page advertisement suggested that manufacturers were responsible for keeping hazardous materials out of their products that eventually would be scrapped and recycled. Materials receiving current attention are polychlorinated biphenyl (PCB), dioxin, and radioactive ferrous scrap.

On May 24, the TAMCO Co., Los Angeles, CA, closed its EAF melt shop after radioactive contamination was discovered. Of the 350-employee work force 3 employees received extensive tests that showed negative results. Fortunately, the radioactive contamination was trapped in 100 tons of baghouse dust.

## TRANSPORTATION

The CSX Corp., formed in 1980 by the merger of Chessie System Railroad Inc. and Seaboard Coast Line Industries Inc., in December 1985 announced a writedown of surplus assets that included 1,000 miles of track, 600 unused locomotives, and 41,000 idle freight cars.

The total annual capability of the U.S. freight-car-building industry in 1985 was 82,000 cars, of which a 29,000-car capacity was completely inactive. Freight car deliveries were 95,650 in 1979, decreasing to 85,465 in 1980, 44,825 in 1981, 17,236 in 1982, and to a low of 5,772 in 1983. Production recovered to more than 12,000 cars in both 1984 and 1985, equal to 15% of production capacity. Of the 1,765 coal-carrying cars ordered in 1985, 1,633 had aluminum sides whose life was expected to be 30 years compared with 20 years for steel sides. Cars for hauling coal in unit trains for electric utilities generally had bottom-emptying hoppers; other cars were emptied by rotary-dump equipment. Such cars usually had a 4,330-cubic-foot internal volume; their payload rating was 106 to 108 tons maximum, their length ranged from 51 to 54 feet, and their empty weight was 15 to 21 tons, of which 31% to 36% consisted of aluminum components. The term "gondola" has been inadvertently used for such coal cars; however, ferrous scrap could not be hauled in such cars because of their configuration and the fact that electric utilities, which owned the cars, specified their use.

Three U.S. makers of aluminum-steel rail cars were Rail Car Co. (Tarco), Ortner Freight Car Co., and Bethlehem Steel Corp.

## PRICES

Based on the average composite delivered prices per long ton quoted monthly and separately by the American Metal Market and Iron Age, No. 1 heavy melting steel scrap cost $74.91 in 1985, ranging from $85.75 in March to $66.58 in June.

The 110,000 gross tons of No. 1 factory bundles auctioned in May by General Motors Corp., Ford Motor Co., and Chrysler Corp. brought $13 to $15 per ton less than in the two preceding months.

In the Pittsburgh area, processors bought only enough scrap to maintain good working relations with their suppliers. Although ferrous scrap sales were classed as bargains, major traders expected higher sales prices because of lower interest rates and the Government's voluntary restraint program on steel imports. When buyers could be found, shredded scrap brought $80 per gross ton, a level at which Pittsburgh scrap could not compete with exports by east coast processors.

In early June, Midwest scrap consumers paid prices near those in 1982 and early 1983. West coast prices were down $1 to $5 per gross ton because of decreasing exports.

Purchases by domestic consumers of scrap from brokers, dealers, and other outside sources were as follows:

| Consumer | Quantity (thousand short tons) | Approximate delivered value | |
|---|---|---|---|
| | | Total (millions) | Average (per ton) |
| Steel manufacturers | 26,866 | $2,124 | $79 |
| Steel castings manufacturers | 1,517 | 133 | 88 |
| Iron castings manufacturers | 8,979 | 682 | 76 |
| Total or average | 37,362 | 2,939 | [1]79 |

[1] Average for the first 6 months was $82, and for the second 6 months, $74.

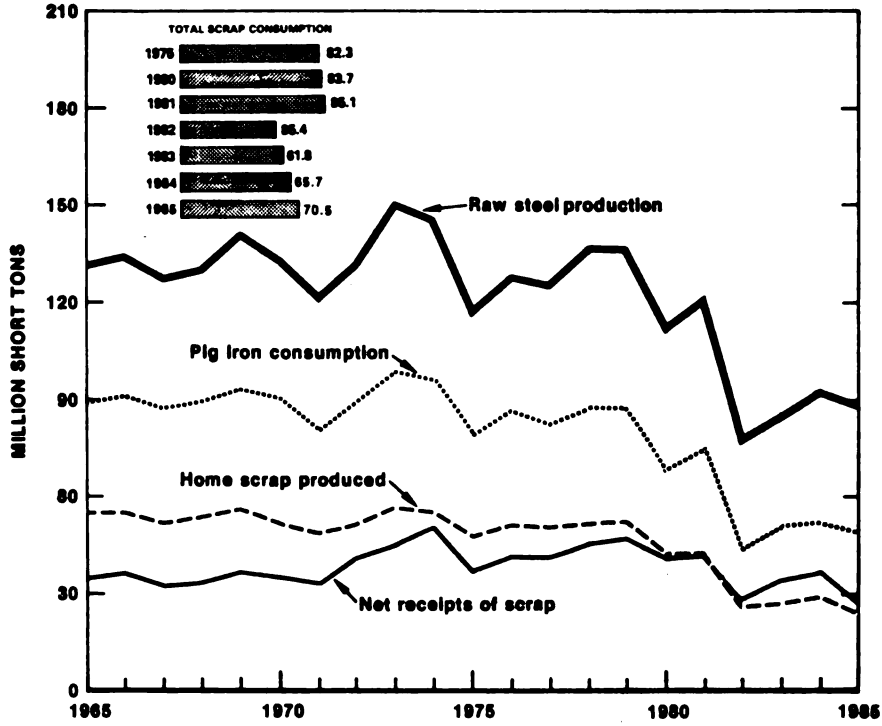

Figure 1.—Raw steel production (AISI), total iron and steel scrap consumption, pig iron consumption, home scrap production, and net scrap receipts.

## FOREIGN TRADE

Total ferrous scrap exports increased 4.7% over those of 1984 and accounted for the largest tonnage since 1980 when 11.2 million tons was exported. The tonnages and values of the 1985 exports, as released by the Bureau of the Census, were as follows:

| Type | Quantity (short tons) | Customs value | |
|---|---|---|---|
| | | Total (thousands) | Average (per ton) |
| Ferrous | 9,639,455 | $794,305 | $82.40 |
| Stainless steel | 179,583 | 104,898 | 584.12 |
| Alloy steel (excluding stainless) | 129,358 | 18,981 | 146.73 |
| Total or average | 9,948,396 | 918,184 | 92.29 |

Canada, Japan, the Republic of Korea, Mexico, Spain, Turkey, and Venezuela collectively received 7.47 million tons, valued at $645 million and averaging $86.35 per ton.

The four countries that received the largest tonnages of U.S. stainless steel scrap exports were Japan, 46,997 tons; Spain, 27,222 tons; the Netherlands, 24,891 tons; and the Federal Republic of Germany, 23,799 tons. Collectively, these countries received 68.6% of the total stainless steel scrap exported. Canada, Sweden, Mexico, Thailand, Taiwan, and India, in decreasing order of tonnage, collectively received 99,528 tons or 76.9% of the total alloy scrap exported.

The tonnages and customs value of the total scrap exported through the five leading customs districts were as follows:

| Area and leading district | Quantity (thousand short tons) | Customs value | |
|---|---|---|---|
| | | Total (thousands) | Average (per ton) |
| East coast: New York, NY | 1,711 | $159,613 | $93.29 |
| Great Lakes: Detroit, MI | 733 | 57,614 | 78.60 |
| Gulf coast: New Orleans, LA | 486 | 66,121 | 136.05 |
| Inland: Laredo, TX | 408 | 40,804 | 100.01 |
| West coast: Los Angeles, CA | 1,320 | 126,055 | 95.50 |
| Total or average | 4,658 | 450,207 | 96.65 |

No. 1 heavy melting and shredded were the leading grades of scrap exported. Collectively, these two grades accounted for 53.5% of the total scrap exported. Borings, shovelings, and turnings totaled 875,000 tons; No. 2 heavy melting totaled 767,000 tons; and iron scrap, excluding borings and shovelings, totaled 666,000 tons. These five grades accounted for 7.63 million tons or 76.7% of all ferrous scrap exports.

The tonnages and values of stainless steel scrap and alloy steel scrap (except stainless) exported from the five leading customs districts, according to the Bureau of the Census, were as follows:

| Area | Quantity (short tons) | Customs value | |
|---|---|---|---|
| | | Total (thousands) | Average (per ton) |
| Detroit, MI: | | | |
| Stainless steel | 4,816 | $3,366 | $698.92 |
| Alloy steel | 20,411 | 2,420 | 118.56 |
| Laredo, TX: | | | |
| Stainless steel | 23 | 43 | 1,869.57 |
| Alloy steel | 12,117 | 2,315 | 191.05 |
| Los Angeles, CA: | | | |
| Stainless steel | 29,597 | 16,847 | 569.21 |
| Alloy steel | 17,632 | 2,215 | 125.62 |
| New Orleans, LA: | | | |
| Stainless steel | 24,749 | 12,777 | 516.26 |
| Alloy steel | 3,518 | 344 | 97.78 |
| New York, NY: | | | |
| Stainless steel | 23,912 | 13,531 | 565.87 |
| Alloy steel | 6,396 | 2,574 | 402.44 |
| Total or average: | | | |
| Stainless steel | 83,097 | 46,564 | 560.36 |
| Alloy steel | 60,074 | 9,868 | 164.26 |

Imports for consumption of iron and steel scrap containing no dutiable alloys totaled 601,000 tons, valued at $45,620,000 and averaging $75.91 per ton. Imports from Canada equaled 93.5% of the total, and imports from Mexico equaled 4.1%.

## WORLD REVIEW

Foreign shipbreaking activities continued to be significant contributors to the ferrous scrap supply, particularly in the Far East.

In 1984, worldwide breakers demolished 1,785 vessels totaling 19.9 million tons. Taiwan, the world leader, broke 7.5 million tons, followed by the Republic of Korea with 4.6 million tons, China with 2.3 million tons, and Japan and Pakistan with 1.3 million tons each.

In 1985, scrapping continued at a high level in Taiwan, the Republic of Korea, and China because of the strong demand for rerolled steel products.

Worldwide in 1985, 987 vessels were scrapped; tankers and combined carriers totaled 251 and represented 56% of the purchased tonnage, and 736 bulk carriers accounted for 44% of the purchased tonnage.

Prices paid by shipbreakers were influenced by the type and size of the vessel. Chinese breakers paid approximately $105 per ton; in Taiwan, very large cargo carriers (VLCC) and 30,000-ton bulk carriers sold for $90 to $96 per ton, and vessels under 4,000 tons were bought for $80 per ton, while Turkish breakers paid $76 per ton for small tonnage vessels.

Because of high labor costs and safety codes in Western Europe, demolition yards similar to those in the Republic of Korea and Taiwan were not economically feasible. Two French supertankers, the *Botillus* and the *Bellamya*, were sold for scrap in October. One vessel went to Taiwan, and the other, to the Republic of Korea.

The Government of Greece approved plans to build a new breaking yard in northern Greece at an estimated cost of $17.5 million. The Japanese Transport Ministry encouraged shipbreaking by way of subsidies and the return of duty paid on vessels imported for scrapping. The Ministry also had plans to use official development funds to construct shipbreaking yards in Burma, Indonesia, Malaysia, and the Philippines. Three Japanese VLCC were sold to a breaking yard in Hakodate Prefecture. A shipbreaking yard in Thailand was scheduled to start operation in December. The yard could scrap three VLCC annually. A new breaking yard started official operation in September at Aliaca in the Izmir region of Turkey. In the startup period, five medium-sized tankers were scrapped. Vessels laid up in nearby Eleusis Bay and the Black Sea were acquired for $76 per ton. A 1.1-million-ton-per-year steel plant was to be built near the Aliaca yard.

The Turkish shipping Zihni Group leased two Government-owned sites at Aliaca where a 1,000-ton-per-day-capacity breaking yard will be built in 2 years.

The shipbreaking yard of H. Stewart (Metals) Ltd., at Birkenhread, United Kingdom, continued in operation despite the loss of its main customer, the minimill of the Manchester Steel Group, at Bidston.

The Government of India shortened the time to obtain a shipbreaking permit to 57 days and readied a $27 per ton tax on ships imported for breaking. The state-owned Metal Scrap Trade Corp. (MSTC) actively sought 6,000- to 6,500-ton ships for breaking. MSTC was the sole buyer of vessels purchased for 90 breaking yards. However, in 1984-85, MSTC supplied only 40 yards; the remaining yards remained idle.

On February 1, 30 vessels averaging 5,500 tons were laid up at Gadani, Pakistan, for scrapping. Because recovered plate was limited to 0.5-inch thickness, only low-tonnage vessels were imported. In mid-May, a consortium of Greek shipowners agreed to supply 20 to 25 vessels annually to Pakistani breakers, whose import duty payment on vessels was increased 5% in May.

In 1984, the revival in world demand for ferrous scrap benefited European processors who found new markets in the Far East. Scrap collection in some European countries improved, thereby making 6.6 million tons total available for export to developing countries.

Worldwide, there were more than 500 shredders whose operators' major problem was finding sufficient supplies of feed materials at the right price.

**Belgium.**—Although export restrictions imposed by the Government had no effect on the total tonnage exported by Belgian processors, Belgian steelmakers demanded urgent action by the European Economic Community (EEC) to restrict EEC scrap exports.

**Brazil.**—Brazil was the world's largest producer of charcoal pig iron, a growing competitor of ferrous scrap. According to the Bank of Brazil's foreign trade department (CACEX), exports of charcoal pig iron in 1984 were 2.76 million tons, reportedly owing in part to the increased ferrous scrap shortage in the world market. The Far East received 60% of the country's production; EEC countries obtained 20%; and the United States, 15%.

Independent pig iron producers in Brazil's Minas Gerais State did not accept a 70% price increase for charcoal to approximately $47 per ton.

**Canada.**—On June 30, two 605-foot lakers, one built in 1957 and the other in 1963, were sold to Cord Steel, Montreal, which resold them to a Curacao, West Antilles, shipbreaking facility. The ships left Montreal July 1 and were towed in single file by the tugboat *Capt. Tonnais S.*

**China.**—Three delegations visited some U.S. ferrous-scrap-processing facilities in the United States to investigate recycling technology and equipment. The delegates made two contracts for purchasing a total of 260,000 tons from the U.S. gulf region for approximately $105 per ton for exports to the ports of Tienchin and Xingang. A major problem in Chinese ports was the unloading of scrap from vessels at a speed commonplace in the Far East; one solution was to receive scrap by vessels that would remain in China for scrapping. Because pig iron receipts could be unloaded at a rate faster than for ferrous scrap, purchases of pig iron stood at 1.0 million tons each from Brazil and Japan in 1985. Pig iron was shipped from three Japanese integrated steelmakers to China Metallurgical Import and Export Corp. Three Chinese groups concerned with scrap purchases were the State Bureau of Supplies, the Ministry of Commerce, and the Ministry of Metallurgy. Local governments were responsible for domestic scrap collection. Industrial scrap was returned for recycling by mandate. Private peddlers collected obsolete scrap predominantly from households, and received payment set by the Government's collection stations where the scrap had to be sold. Thyssen Henschel of the Federal Republic of Germany sold several 1,250-ton-force scrap shears to Chinese steelworks.

**Czechoslovakia.**—The state-owned scrap processor Kovosrot Brno obtained equipment and technology for a continuous detinning process developed and operated by the United Kingdom processor Vulcan Materials. The new plant was expected to convert 30,000 tons annually of low-quality tinplate scrap into high-quality detinned steel scrap and high-grade secondary tin ingots.

**Denmark.**—The newly-formed SR Scandinavian Recycling AB established a marketing arrangement with the E. Laursen Maskinfabrik A/S. Two shredders and two grinders in Denmark had a 4,250 total horsepower and a single-shift annual capacity of 75,000 tons.

**European Communities (EC).**—In late February, the European Committee of the National Ferrous Scrap Association rejected an EC proposal for a ferrous-scrap-sale monitoring system because it would result in an advantage to U.S. scrap merchants. A below normal U.S. steel output further depressed European scrap prices. Nuova Campsider of Italy attempted to restrict Italian ferrous scrap exports. In a March 26 meeting, EC ministers for industrial affairs ruled out the possibility of ferrous scrap export controls. In 1984, ferrous scrap consumption in the EC was less than 6% greater than that in 1983. The EC scrap supply situation eased because of lower prices prompted by the decrease in the dollar exchange rate. EC officials reported that EC steelmakers no longer faced supply shortages, although in some situations the demand for low-residual scrap exceeded the supply. The main reason for a $30 per ton decrease in the British stainless steel scrap price was attributed to the strengthening of the pound sterling against the dollar.

**France.**—In 1984, exports of ferrous scrap totaled 4.5 million tons, of which 2.1 million tons went to Italy. More than one-half of the French scrap iron consumption came from home scrap, and 5%, from imports. Imports in the first 8 months of 1984 totaled 364,000 tons. Cie. Française de Ferailles planned to install one shredder in its Bordeaux yard and another in its Toulouse yard primarily to supply the Spanish ferrous scrap market. Metalinor, formed by the merger of Otto Lazar and Vidal & Champreddonder, became one of Europe's biggest scrap dealers. The presence of new EAF's, notably in steel mills at Neuves-Maisons, Hagendange, and Valenciennes, reportedly could increase the annual domestic demand for scrap iron by 1.1 million tons.

**Germany, Federal Republic of.**—In late March, the Iron and Steel Industry Association filed a case against the EC Commission concerning its failure to prevent Italian subsidies on ferrous scrap imports. Other steel federations had not made similar objections in late March. The short-term availability of ferrous scrap eased, and there were no indications of a major turndown in supplies although higher quality grades were barely sufficient to meet demand. Steelmakers used 19 kilograms less scrap per metric ton of steel produced, bringing the average to 347 kilograms in the first half of 1985 because of the high price of scrap in this time period. Beitrage zur Danziger Statistik, the West German scrap federation, reported 1.65 million tons of ferrous scrap exports in the first 5 months of 1985 and imports of 1.2 million tons.

The EC Commission approved the acquisition of Walter Trapp GmbH by Thyssen Sonnenberg, which gave the company a 27% share of the West German scrap market and more than an 8% share of the EC trade. Thyssen AG merged its subsidiaries Thyssen Sonnenberg (Duisburg) and Thyssen Carbometal Co. (New York) into a single company. Elg Haniel GmbH (Duisberg) appointed Kinsho Mataich as Japanese sales agent for Elg's stainless steel scrap, special steel scrap, and rare metal scrap. Kinshofer Maschinefabrik designed a hydraulic ram to handle thin-gauge scrap.

**India.**—Imports of ferrous scrap were principally baled shredded because in past years some receivers obtained usable and rerolling material and fraudulently declared it for assessed import duty as heavy melting steel scrap. Four tenders submitted to the MSTC, the last in early November 1985, totaled 556,000 metric tons in the range of $116 to $128 per metric ton. Traders included Nissho-Iwai Corp. from (Japan), the Associated Minerals Consolidated Ltd. (United Kingdom), the Independent Bulk Commodity Trading Ltd. (United Kingdom), Krupp AG (Federal Republic of Germany), and Hugo Neu (United States). Receiving ports were Bhovnagar, Bombay, Calcutta, Kandla, Madras, and Vizagapatnam. Most scrap was bought by MSTC, a Government agency, through tenders from a limited number of participants. Eventually, the successful bidder had to establish an unconditional performance bond. Then, it often required 14 days until the seller had a workable letter of credit (LC) in hand, and during this time period, the seller decided on the source of scrap, the chartering of a vessel, and exchange transactions. India always includes a 180-day term in the LC and often converted U.S. dollars in the calculation of the sale price.

Shipments to India were not the easiest. Recurring factors were port and vessel restrictions, frequent congestion in ports, wildcat strikes, a shortage of trucks to receive the cargo directly from vessels, and the monsoon period in June through August. Substantial demurrage charges developed from the foregoing factors. The latest development in scrap shipments to India was an indefinite quality control procedure introduced by the MSTC, which dictated to the inspection company handling 100,000-ton minimum orders placed under tender T-11.

**Ireland.**—Irish Steel Ltd.'s board considered a partial or total closure of its works during a cashflow crisis in early 1985 because of high scrap prices contracted in 1984 that could not be passed along by way of higher steel prices. The firm had to pay $4.5 million more for scrap in the first half of 1985.

**Italy.**—The decreased output of EAF steel was attributed to high scrap prices within the EC because of reduced levels of supply. Price was the deciding factor for Soviet and U.S. ferrous scrap contracts. Supplies from Middle East and African sources were insufficient to meet the EAF demands. The decline in the dollar in October resulted in a 15% decline in Italian scrap prices. Italy had 20 shredders with an annual single-shift capacity of 600,000 tons.

**Japan.**—Major ferrous scrap traders were C. Itoh & Co. Ltd., Hyuka Sangyo, Japanese Kanematsu Gosho Ltd., Marubeni Corp., Mitsubishi Corp., Mitsui & Co., Nissho-Iwai, Okaya Koki, Sumitomo Corp., Takunam Seitetau, Tokyo-Takko, and Toyo-Menka.

Domestically available ferrous scrap moved in significant tonnages to steelmakers. Eight companies in the Kyushu region bought 105,000 metric tons in June and July. The companies were Nippon Steel Corp., Sumitomo Metal Industries Ltd., Tokai Steel Works Ltd., Kiyomato Tekko K.K., Showa Kogyo K.K., Nishinhon Seiko K.K., Nikon Chutanko K.K., and Hitachi Metals Ltd. In the February to November period, Nippon Steel bought 43,900 metric tons of domestic scrap, and Nippon Kokan Steel Corp. obtained 4,000 to 5,000 metric tons monthly from the Tokyo Yohahama area. The Kanto region in eastern Japan sent 60,000 metric tons in April to the Humaji and Osaka areas.

Japan had 50 shredders each rated at more than 1,000 horsepower and 54 shredders in the 100- to 800-horsepower range.

In December, the Japan Steel Scrap Reserves Association, a joint group of steelmakers and merchants, boosted local ferrous scrap prices in the Kanto region. The average of 12 midmonth quotations of the Tex Report are shown for 5 types of ferrous scrap purchased in 1985 by major EAF mills in the Kanto region, in dollars[3] per metric ton and using Japanese scrap-trade terminology, were as follows:

| Type | Price |
|---|---|
| Cut and pressed | $112.52 |
| Extra special | 112.45 |
| Special G-2 | 105.70 |
| Turnings A | 90.89 |
| Press A | 80.41 |

The delivered price for H-2 scrap to seven areas of Japan, as reported in the Tex Report, January 9, 1986, and in dollars per metric ton, were as follows:

| Area | Price |
|---|---|
| Kansai | $113.05 |
| Chungoku-Shikoku | 108.43 |
| Kuyushu | 108.21 |
| Kanto | 105.22 |
| Chubu | 99.90 |
| Tohuku | 99.72 |
| Hakkaido | 98.00 |

Dealer quotations for SUS 18/8 Sabot-grade stainless steel scrap in dollars per metric ton cost, insurance, and freight (c.i.f.) Japan, were obtained from all relevant issues of the Tex Report in 1985. The average of 183 quotations for Hong Kong cargo was $628.90; for 178 quotations for U.S. cargo from the west coast, the average was $630.92.

The Tex Reports for 1985 published 54 instances of f.o.b. values and freight rates of ferrous scrap exported from the U.S. east coast and 54 instances of f.o.b. values and freight rates for the U.S. west coast. Data in dollars per ton were as follows: East coast exports averaged $77.56 f.o.b. in a range from $72.46 to $84.39, and freight averaged $16.48 in a range from $12.73 to $19.64. Exports from the U.S. west coast averaged $79.71 f.o.b. in a range from $75.38 to $87.05, and freight averaged $14.07 in a range from $13.39 to $14.73.

Pig iron imported by Japan in 1985 totaled 747,579 metric tons (equal to 23.0% of the tonnage of all ferrous scrap imports), averaging $132.83 per metric ton. The Republic of South Africa supplied 299,991 tons at $122.74 per ton, and Brazil supplied 140,967 tons at $139.64 per metric ton.

Imports of all types of ferrous scrap in 1985 totaled 3,253,534 metric tons averaging $125.09 per ton, according to the Japan Iron and Steel Federation in the Tex Report of March 14, 1986.

According to the Bureau of the Census, U.S. Department of Commerce, exports of 11 grades of U.S. ferrous scrap to Japan totaled 2,110,086 tons averaging $94.37 per ton. The U.S.S.R. was the second largest supplier of ferrous scrap to Japan with 400,241 metric tons averaging $98.96 per metric ton.

According to the Tex Report of February 19, 1986, quantity and average value of Japanese exports of pig iron and ferrous scrap, in metric tons and dollars per metric ton, were as follows:

| Material | Quantity | Average value |
|---|---|---|
| Pig iron | 1,066,307 | $125.45 |
| Scrap: | | |
| Cast iron | 5,937 | 103.51 |
| Steel | NA | 189.86 |
| Alloy steel | 458 | 181.62 |

NA Not available.

Japanese exports of pig iron to China totaled 1,003,889 metric tons valued at $124.49 per ton.

Production of pig iron was about 79.0 million metric tons, and of raw steel, about 103.6 million, both down from the levels in the preceding fiscal year. EAF raw steel production equaled 30.2 million metric tons. Stocks of ferrous materials (pig iron and scrap iron) totaled 5.5 million metric tons, up from 4.8 million tons at the end of fiscal year 1984.

Missions for the Japanese stainless steel industry to study ferrous-scrap-processing operations spent April 27 to May 13 in the United States and Brazil. A mission from the Kansai Scrap Association was in the United States on May 14. These missions were planned to continue indefinitely at 3-month intervals.

**Korea, Republic of.**—According to the Korean Iron & Steel Association, EAF steel production totaled 4.25 million metric tons in 1985 and 3.84 million in 1984; converter raw steel production totaled 9.28 million metric tons in 1985 and 9.20 million in 1984. EAF mills were operated by Dongkuk Steel Mill Co. Ltd., Hanbo Steel Co. Ltd., Inchon Iron & Steel Co. Ltd., and Kang Won Industries. Imports of steel scrap were 2.76 million metric tons for melting and 0.80 million for rerolling; respective tonnages in 1984 were 2.32 million and 0.79 million. Monthly average stocks of ferrous scrap were 238,000 metric tons in 1985 and 135,000 in 1984. Domestically purchased scrap in 1985 for melting totaled 2.16 million metric tons and 1.94 million in 1984.

**Netherlands.**—The new European S terminal operated by the Dutch stevedoring company Dalmeijer's Metalen BV was expected to attain, in 3 years, an annual throughput of 1.5 million metric tons. The terminal has four cranes and can load two 60,000-ton cargoes simultaneously. In 1985, only grades OA, No. 1, No. 2, and shredded were handled. A ninth shredder started operation in the Netherlands bringing total horsepower to 11,100 and annual single-shift capacity to 450,000 metric tons, roughly equal to the amount of feed available.

**South Africa, Republic of.**—National Metals, a ferrous and nonferrous scrap processor, installed equipment on a site near Pretoria owned by state-owned steelmaker South African Iron and Steel Industrial Corp. Ltd. (Iscor). The steelmaker had no equity in the operation and was not obliged to take scrap from National Metals. Domestic steelworks annual consumption was expected to reach 2.5 million tons in 1986, 2.5% more than total overall domestic scrap. Some of the shortfall will be met by sponge iron costing $75 per metric ton compared with $45 per ton for high-grade ferrous scrap. In mid-1986, Iscor exported heavily from its substantial ferrous scrap stockpile. Since 1977, Iscor and Korf Stahl AG developed modification of a direct-reduced-iron (DRI) process using South African noncoking coal. Other steelmakers producing coal-based DRI were Dunswart, operating a 140,000-ton-per-year Codir plant supplied by Krupp, and Scaw Metals Ltd., producing 90,000 tons annually in a Direct Reduction Corp. DRI plant. Union Steel Corp.'s Vaal works operated the only gas-based DRI plant using synthetic gas from the nearby Sasol plant. Davsteel (Pty.) Ltd. made DRI in a converted small rotary kiln.

**Spain.**—In the first 9 months of 1985, imports of ferrous scrap totaled 4.0 million metric tons. The United Kingdom supplied 2.1 million tons; France, 0.9 million; the United States, 0.7 million; and the U.S.S.R., 0.3 million. Beginning January 1, 1986, Spanish steelmakers must pay a 12% value-added tax (VAT) on imported ferrous scrap instead of the current 2% duty. The number of steel foundries decreased from 66 in 1977 to 53 in 1983, thereby reducing the annual output from 160,000 tons to 150,000 tons, and the number of employees by 12%. The Spanish scrap industry declared impractical a proposal to concentrate the buying of ferrous scrap by a Government agency. The Spanish steelmaker Empresa Nacional Siderúrgica S.A. sold 175,000 tons of ferrous scrap in both 1983 and 1984. The firm adhered to a 1-year-old policy and bought no scrap from either domestic or foreign sources in 1985, according to Metales y Máquinas.

**Taiwan.**—Imports of ferrous scrap were stagnant in February 1985; only state-run plants with sufficient funds or other mills, compelled to make purchases, were in the market. Several influential EAF mills were consolidated to make radical changes in the supply-demand situation, and only minor imports of scrap were made. In early November, a reduction of import duty stimulated scrap imports.

**Turkey.**—In November, Cukorova's Aliaca works became Turkey's largest electric steelmaker with an annual capacity of 1.0 million metric tons, although the 1984 output of raw steel was only 0.4 million metric tons. The Habas Group was installing two 75-ton EAF's at Izmir. Asil Celik, almost entirely state-owned and Turkey's principal specialty steelmaker, experienced serious financial problems. In 1985, Asil bought about 100,000 metric tons of scrap from the United States, the United Kingdom, and the Federal Republic of Germany. Plans were under way to buy 40,000 tons of domestic scrap in 1986, up 18,000 tons from those in 1985.

**United Kingdom.**—The increased use of EAF's helped maintain a strong domestic demand for ferrous scrap. The steel industry's scrap stocks were 450,000 metric tons at yearend 1984 compared with 858,000 metric tons in 1980. In August, the British Steel Corp. (BSC) announced a 3-year strategic plan that could lead to a fundamental shift in scrap purchasing in the United Kingdom. BSC expected to use more scrap to reduce its reliance on blast furnaces.

The United Kingdom exported about 50% of its total available ferrous scrap. Quantity and average value of ferrous scrap exports during the first 11 months of 1985, in thousand metric tons and dollars per ton, were as follows:

| Material | Quantity | Average value |
|---|---|---|
| Iron and steel | 3,823 | $71.65 |
| Cast iron | 292 | 71.58 |
| Stainless steel | 30 | 456.67 |
| Alloy steel | 14 | 614.29 |

In this 11-month period, total exports to developing countries totaled 3,527,000 metric tons and averaged $73.89 per metric ton. In the first half of 1985, total exports were 2,479,000 metric tons, of which 59.9% went to Spain, 11.2% to Sweden, 4.6% to the German Democratic Republic, 3.7% to the Federal Republic of Germany, and 19.6% to all other countries. The unexpected very large exports of U.S. scrap in August 1985 (an all-time high monthly record) affected the British traditional markets in Europe and the Mediterranean area. The managing director of a British exporter, Mayer Newman and Co. Ltd., claimed that port dues and other high costs drove exports away from British shippers to European competitors. A 32,000-metric-ton cargo of shredded scrap sank in the Red Sea enroute to India. The $4 million cargo was shipped by Sheppard Waste Recovery Ltd. from Liverpool.

The British Scrap Federation (BSF), in February, asked British steelmakers to put political pressure on Italy and Spain to remove their subsidies on scrap imports. Two major protagonists who complained to the Department of Trade and Industry about an anticipated lack of ferrous scrap set up their own processing and marketing subsidiaries.

Billiton (U.K.) Ltd. reorganized its Billiton International Metals BV ferrous business by locating to a quayside site on the Manchester Ship Canal at Irwell Park, Eccles. The Hulbert of Dudley scrap metal division, after 50 years of trading mostly in the Midlands, entered the bulk export market. Hulbert chartered its own vessels to ship 1,000- to 2,000-ton cargoes of graded steel scrap to the Mediterranean area and to move container lots to continental users. Such low-tonnage cargoes were requested by customers who maintained low inventories to improve their cash-flow situation. London Metals moved its activities to larger premises in Cannonburg, North London. A. R. Brown, McFarlane & Co., acquired the scrap exporter Arnott Young Ltd. from Tarmac Roadstone Holdings Ltd. Arnott Young will continue to trade under its own name from its dock at Dalmuir, Clydebank. BSC and other British steelmakers asked their suppliers to accept unchanged prices for September 1985 scrap deliveries. BSC reduced its surcharge from $28 to $13 per metric ton in line with the downward drift of ferrous scrap prices. The surcharge was calculated using Metal Bulletin's Ferrous Scrap Market Index. Scrap prices strengthened in December because of rising exports and local shortages in the United Kingdom. Spanish steelmakers built up stockpiles prior to Spain's entry into the EC when Spanish receipts would be subject to higher taxes effective January 1, 1986. Rising prices for ferrous scrap, pig iron, and foundry coke were blamed for British foundries' increased costs, according to the British Foundry Association (BFA). BFA claimed that suppliers of pig iron and foundry coke enjoyed a virtual monopoly because they were mainly "nationalized industries."

A report by Marketing Strategies for Industry, entitled "MSI Data Base: Foundries and Castings, United Kingdom, July 1985," and a survey by a Department of Trade and Industry's Business Statistics Office disclosed that over one-half of British iron foundries terminated production in the 1974-83 period. The annual output of castings decreased from 3.45 million metric tons to 1.45 million metric tons in the same time period. Productivity per person per year fell marginally to 39 metric tons, probably reflecting a trend to lighter, higher value castings. The ferrous scrap industry comprised 400 BSF members and about 9,500 registered scrap dealers. The 400 members operated 70 fragmentation plants, 300 shears ranging from 300 to 2,000 tons of shear force, and hydraulic balers whose annual capacity was 400,000 metric tons of No. 1 bales. A new inland scrap-loading wharf on the River Trent at Readby, Humberside, was managed by the Associated Waterway Services Ltd. Four "purpose-built" scrap bundlers were installed in the Tipton Works of Firth Cleveland Steel Strip Ltd. Edgar Allen Developments Ltd. designed a shredder that could handle automobiles and domestic appliances without the need for precrushing or shearing. Sheppard Waste Recovery at Rochdale ordered a large shear from Thyssen Henschel of the Federal Republic of Germany costing about $2.7 million.

Modifications to British iron and steel scrap specifications became effective November 1 following months of discussions involving the BSF, BSC, and British Independent Steel Producers Association (BISPA). The modifications included the views of the BFA. In summary, 4 general conditions were applicable to 26 grades of scrap. These modifications replaced those of August 1980.

**U.S.S.R.**—Much scrap for export tended to be hand sorted, and the quality reportedly was generally good. The Soviet's selling policy did not appear to follow usual commercial practice; accordingly, the Spanish steel industry built up a barter scheme for scrap movements. The U.S.S.R. trade organization Promsyrioimport sent 20,000 metric tons of scrap from a Black Sea port to Japan at $100 per ton c.i.f. Generally, Soviet scrap to Japan originated at Siberian ports.

**Venezuela.**—Ferrous scrap imports at 600,000 tons per year were predicted to decrease to 200,000 tons in the next few years as the domestic production of DRI increased. DRI output is currently limited because the only merchant plant, operated by Fior de Venezuela S.A., concentrates on the export market. C.V.G. Siderúrgica del Orinoco C.A.'s Hojalata y Lámina S.A. DRI facilities continued to have technical operating problems.

## TECHNOLOGY

The Consteel continuous steelmaking process permits the use of purchased ferrous scrap having various qualities, limited preparation, and maximum dimensions. Generally, 2- by 2-foot scrap can be charged continuously; when factory bundles are similarly charged, the preheating efficiency decreases. Intersteel Technology Inc., Charlotte, NC, is the vendor of the process.[4]

More than 200 tons of scrap iron from the Statue of Liberty and Ellis Island was converted into metal powders destined to make commemorative souvenirs; the conversion was done by the Hoeganaes Corp., Riverton, NJ.[5]

The current use of galvanized ferrous scrap in EAF operations produces 0.5 million tons of dust and fume annually, mostly comprising iron oxides. These solids are trucked to conventional landfills. By 1988, this tonnage is predicted to reach 3.0 million tons per year as electrogalvanized steel production lines are increased to double the output of galvanized products. The fabrication of such products will increase the zinc content of home scrap and industrial-grade bundled scrap. The EPA now designates EAF dusts and fumes produced during the melting of galvanized scrap as hazardous because of their contained cadmium, lead, and zinc. Currently, the total of these three metals is limited to 1,000 kilograms per month per melting furnace. Because the smelting of the collected dusts and fumes to reclaim these metals is impractical, larger haulage costs to special landfills are inevitable. Further, pelletized dust, although high in iron oxide content, cannot be added to blast furnace burden because it forms scabs and causes spalling of the refractory lining.

Currently, industrial scrap bundles are the principal source of the zinc contaminant. Zinc contamination from an automobile hulk is relatively small owing to the oxidation of zinc metal to zinc oxide during the vehicle's lifetime.[6]

The Center for Metals Production and the America Iron and Steel Institute (AISI) planned research that focused on the recycling of EAF dust and fumes back into the EAF. The purpose is to increase the concentration of zinc and other metals in the dust and fumes to enhance their economic recovery.[7] Other research on recovery of zinc from steel plant dusts was reported at the "International Symposium on Recycle and Secondary Recovery of Metals." The processes are designed for zinc recovery by leaching techniques.[8]

NARI and the Bureau of Mines extended an agreement, terminating in May 1987, for research on scrap metal recovery, processing, and technology. The agreement provided for the development and exchange of information relating to the processing of scrap metal and waste, and the rapid identification of components.[9]

Phoenix Metals Corp., Plymouth, MI, planned the startup of a 20,000-ton-per-year plant to convert machine shop turnings into powder suitable for making powdered metal parts and welding electrodes. This plant will use a comminution process licensed from the Ford Motor Co.[10]

Preliminary results of joint research conducted by the U.S. Department of Energy and ISIS indicated that untreated shredder scrap residues have the energy equivalent of low-grade bituminous coal. These residues could be suitable for steam generation in equipment using specially designed combustion controls. Combustion of the residues results in no emission problems; however, data on the stability of the heavy metals content in the resulting ash was incomplete.[11]

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[1] Physical scientist, Division of Ferrous Metals.

[2] All quantities are in short tons unless otherwise specified.

[3] Where necessary, values have been converted form Japanese yen (Y) to U.S. dollars at the rate of Y237 = US$1.00.

[4] American Metal Market. V. 93, No. 25, Feb. 6, 1985, p. 12.

———. V. 93, No. 104, May 30, 1985, p. 8.

[5] Recycling Today. V. 23, No. 6, June 1985, p. 74.

[6] American Metal Market. V. 94, No. 1, Jan. 2, 1986, p. 8.

[7] Phoenix Quarterly. V. 17, No. 4, Winter 1986, p. 11.

[8] Taylor, P. R., H. Y. Sohn, and N. Jarrett. Paper in Proceedings of the International Symposium on Recycle and Secondary Recovery of Metals. Metall. Soc., pp. 143-157, 195-201.

[9] Work cited in footnote 4.

[10] 33 Metal Producing. V. 23, No. 4, Apr. 1985, p. 53.

[11] American Metal Market. V. 93, No. 100, May 23, 1985, p. 9.

## Table 2.—U.S. consumer receipts, production, shipments, and stocks of iron and steel scrap and pig iron in 1985, by grade

(Thousand short tons)

| Grade | Receipts of scrap | | Production of home scrap | | Consumption of both purchased and home scrap (includes recirculating scrap) | Shipments of scrap | Ending stocks, Dec. 31 |
|---|---|---|---|---|---|---|---|
| | From brokers, dealers, other outside sources | From other own-company plants | Recirculating scrap resulting from current operations | Obsolete scrap (includes ingot molds, stools, scrap from old equipment, buildings, etc.) | | | |
| **MANUFACTURERS OF PIG IRON AND RAW STEEL AND CASTINGS** | | | | | | | |
| Carbon steel: | | | | | | | |
| Low-phosphorus plate and punchings | 331 | -- | 3 | 4 | 336 | 5 | 21 |
| Cut structural and plate | 858 | 192 | 382 | 12 | 1,523 | 16 | 102 |
| No. 1 heavy melting steel | 8,062 | 1,368 | 8,565 | 143 | 16,941 | 1,297 | 1,107 |
| No. 2 heavy melting steel | 2,560 | 234 | 920 | 4 | 3,604 | 126 | 291 |
| No. 1 and electric-furnace bundles | 5,246 | 227 | 1,597 | 3 | 7,072 | 476 | 402 |
| No. 2 and all other bundles | 1,015 | 36 | 11 | (1) | 1,105 | 8 | 88 |
| Electric furnace, 1 foot and under (not bundles) | 40 | 46 | 25 | (1) | 97 | 1 | 24 |
| Railroad rails | 169 | 1 | 2 | -- | 222 | 2 | 2 |
| Turnings and borings | 782 | 10 | 266 | 1 | 1,069 | 14 | 76 |
| Slag scrap (70% Fe content) | 542 | 122 | 2,452 | 1 | 2,815 | 306 | 184 |
| Shredded or fragmentized | 2,774 | 1,188 | 175 | -- | 4,043 | 129 | 264 |
| No. 1 busheling | 1,296 | 32 | 185 | 1 | 1,466 | 116 | 77 |
| All other carbon steel scrap | 1,800 | 660 | 6,382 | 11 | 8,149 | 840 | 596 |
| Stainless steel scrap | 512 | 21 | 478 | (1) | 1,000 | 19 | 76 |
| Alloy steel (except stainless) | 126 | 162 | 1,019 | 1 | 1,256 | 94 | 229 |
| Ingot mold and stool scrap | 274 | 232 | 549 | 773 | 1,443 | 411 | 314 |
| Machinery and cupola cast iron | 2 | -- | 4 | 1 | 5 | 6 | 1 |
| Cast-iron borings | 106 | (1) | 7 | (1) | 89 | 26 | 11 |
| Motor blocks | -- | -- | -- | -- | (1) | -- | (1) |
| Other iron scrap | 163 | 96 | 456 | 1 | 528 | 169 | 75 |
| Other mixed scrap | 210 | 74 | 128 | 6 | 437 | 3 | 22 |
| Total[2] | 26,866 | 4,701 | 23,605 | 962 | 53,201 | 4,063 | 3,964 |
| **MANUFACTURERS OF STEEL CASTINGS** | | | | | | | |
| Carbon steel: | | | | | | | |
| Low-phosphorus plate and punchings | 488 | 2 | 119 | -- | 566 | (1) | 43 |
| Cut structural and plate | 125 | 27 | 14 | -- | 172 | -- | 10 |
| No. 1 heavy melting steel | 61 | (1) | 50 | -- | 111 | -- | 8 |
| No. 2 heavy melting steel | 131 | -- | 1 | -- | 140 | -- | 4 |
| No. 1 and electric-furnace bundles | 11 | 1 | -- | -- | 8 | -- | (1) |
| Electric furnace, 1 foot and under (not bundles) | 48 | 1 | 6 | (1) | 55 | 1 | 3 |
| Railroad rails | 4 | -- | -- | -- | 3 | -- | 1 |
| Turnings and borings | 32 | -- | 11 | -- | 40 | 2 | 1 |
| Slag scrap (70% Fe content) | -- | -- | (1) | -- | -- | (1) | -- |
| Shredded or fragmentized | 28 | -- | -- | -- | 28 | -- | (1) |
| No. 1 busheling | 13 | -- | -- | -- | 8 | (1) | 2 |
| All other carbon steel scrap | 311 | 67 | 116 | 2 | 474 | 4 | 45 |
| Stainless steel scrap | 20 | 1 | 18 | (1) | 35 | 1 | 7 |
| Alloy steel (except stainless) | 59 | -- | 141 | (1) | 198 | 3 | 57 |
| Ingot mold and stool scrap | 9 | -- | (1) | -- | 9 | (1) | (1) |
| Machinery and cupola cast iron | (1) | -- | 1 | -- | 3 | -- | (1) |
| Cast-iron borings | 67 | -- | 33 | -- | 87 | -- | 9 |
| Other iron scrap | 105 | -- | 31 | (1) | 127 | 4 | 23 |
| Other mixed scrap | 3 | -- | 9 | -- | 12 | -- | (1) |
| Total[2] | 1,517 | 100 | 549 | 2 | 2,075 | 15 | 213 |

See footnotes at end of table.

## Table 2.—U.S. consumer receipts, production, shipments, and stocks of iron and steel scrap and pig iron in 1985, by grade —Continued

(Thousand short tons)

| Grade | Receipts of scrap |  | Production of home scrap |  | Consumption of both purchased and home scrap (includes recirculating scrap) | Shipments of scrap | Ending stocks, Dec. 31 |
|---|---|---|---|---|---|---|---|
|  | From brokers, dealers, other outside sources | From other own-company plants | Recirculating scrap resulting from current operations | Obsolete scrap (includes ingot molds, stools, scrap from old equipment, buildings, etc.) |  |  |  |
| **IRON FOUNDRIES AND MISCELLANEOUS USERS** |  |  |  |  |  |  |  |
| Carbon steel: |  |  |  |  |  |  |  |
| Low-phosphorus plate and punchings | 1,005 | 113 | 298 | 10 | 1,349 | 11 | 141 |
| Cut structural and plate | 1,154 | 6 | 108 | (1) | 1,309 | 1 | 59 |
| No. 1 heavy melting steel | 112 | 46 | 289 | -- | 197 | 244 | 20 |
| No. 2 heavy melting steel | 247 | -- | 23 | -- | 271 | 1 | 6 |
| No. 1 and electric-furnace bundles | 113 | 151 | 43 | -- | 317 | -- | 9 |
| No. 2 and all other bundles | 189 | 78 | (1) | -- | 266 | (1) | 28 |
| Electric furnace, 1 foot and under (not bundles) | 30 | 3 | 7 | -- | 36 | -- | 3 |
| Railroad rails | 134 | -- | 5 | -- | 141 | 2 | 10 |
| Turnings and borings | 455 | 5 | 2 | 4 | 453 | 8 | 52 |
| Slag scrap (70% Fe content) | 11 | -- | -- | -- | 9 | 2 | 2 |
| Shredded or fragmentized | 992 | 159 | 114 | -- | 1,271 | 3 | 72 |
| No. 1 busheling | 447 | 70 | 123 | -- | 629 | (1) | 18 |
| All other carbon steel scrap | 366 | 2 | -- | -- | 472 | 4 | 51 |
| Stainless steel scrap | 27 | -- | 7 | (1) | 31 | 4 | 2 |
| Alloy steel (except stainless) | 29 | -- | 4 | 5 | 34 | 5 | 15 |
| Ingot mold and stool scrap | 124 | 12 | 153 | (1) | 307 | 4 | 52 |
| Machinery and cupola cast iron | 889 | 8 | 267 | 20 | 1,166 | 23 | 59 |
| Cast-iron borings | 977 | 280 | 85 | 1 | 1,306 | 31 | 52 |
| Motor blocks | 466 | 29 | 825 | -- | 1,301 | 25 | 52 |
| Other iron scrap | 702 | 183 | 2,572 | 1 | 3,459 | 53 | 128 |
| Other mixed scrap | 508 | 39 | 337 | 26 | 890 | 27 | 96 |
| Total[2] | 8,978 | 1,182 | 5,263 | 67 | 15,217 | 449 | 927 |
| **TOTAL—ALL TYPES OF MANUFACTURERS** |  |  |  |  |  |  |  |
| Carbon steel: |  |  |  |  |  |  |  |
| Low-phosphorus plate and punchings | 1,824 | 114 | 420 | 14 | 2,251 | 16 | 205 |
| Cut structural and plate | 2,138 | 224 | 503 | 12 | 3,005 | 17 | 171 |
| No. 1 heavy melting steel | 8,236 | 1,415 | 8,903 | 143 | 17,249 | 1,541 | 1,134 |
| No. 2 heavy melting steel | 2,938 | 234 | 943 | 4 | 4,016 | 127 | 301 |
| No. 1 and electric-furnace bundles | 5,370 | 379 | 1,641 | 3 | 7,397 | 476 | 411 |
| No. 2 and all other bundles | 1,204 | 114 | 12 | (1) | 1,372 | 8 | 115 |
| Electric furnace, 1 foot and under (not bundles) | 119 | 49 | 31 | (1) | 188 | 2 | 30 |
| Railroad rails | 307 | 1 | 10 | -- | 365 | 4 | 14 |
| Turnings and borings | 1,269 | 15 | 282 | 5 | 1,561 | 24 | 129 |
| Slag scrap (70% Fe content) | 553 | 122 | 2,454 | 1 | 2,824 | 308 | 186 |
| Shredded or fragmentized | 3,794 | 1,347 | 175 | -- | 5,342 | 182 | 336 |
| No. 1 busheling | 1,756 | 102 | 299 | 1 | 2,103 | 117 | 96 |
| All other carbon steel scrap | 2,477 | 729 | 6,620 | 13 | 9,095 | 849 | 693 |
| Stainless steel scrap | 558 | 23 | 503 | (1) | 1,066 | 24 | 85 |
| Alloy steel (except stainless) | 215 | 162 | 1,164 | 6 | 1,488 | 101 | 301 |
| Ingot mold and stool scrap | 406 | 244 | 703 | 773 | 1,759 | 416 | 366 |
| Machinery and cupola cast iron | 892 | 8 | 272 | 21 | 1,174 | 29 | 60 |
| Cast-iron borings | 1,150 | 280 | 124 | 2 | 1,482 | 57 | 73 |
| Motor blocks | 466 | 29 | 825 | -- | 1,302 | 25 | 53 |
| Other iron scrap | 970 | 278 | 3,059 | 2 | 4,115 | 225 | 225 |
| Other mixed scrap | 720 | 113 | 474 | 32 | 1,339 | 30 | 118 |
| Grand total[2] | 37,362 | 5,983 | 29,416 | 1,032 | 70,493 | 4,527 | 5,104 |

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

## Table 3.—U.S. consumer receipts, production, consumption, shipments, and stocks of pig iron and direct-reduced iron in 1985

(Thousand short tons)

| | Receipts | Production | Consumption | Shipments | Stocks, Dec. 31 |
|---|---|---|---|---|---|
| MANUFACTURERS OF PIG IRON AND RAW STEEL AND CASTINGS | | | | | |
| Pig iron | 1,074 | 49,963 | 49,833 | 1,287 | 188 |
| MANUFACTURERS OF STEEL CASTINGS | | | | | |
| Pig iron | 71 | -- | 68 | (1) | 4 |
| IRON FOUNDRIES AND MISCELLANEOUS USERS | | | | | |
| Pig iron | 1,566 | -- | 1,510 | 69 | 72 |
| TOTAL—ALL TYPES OF MANUFACTURERS | | | | | |
| Pig iron | 2,711 | 49,963 | 51,411 | 1,356 | [2]266 |
| Direct-reduced or prereduced iron | 359 | -- | 349 | W | 52 |

W Withheld to avoid disclosing company proprietary data.

[1] Less than 1/2 unit.

[2] Data do not add to total shown because of independent rounding.

## Table 4.—Consumption of iron and steel scrap and pig iron in the United States in 1985, by type of furnace or other use

(Thousand short tons)

| Type of furnace or other use | Manufacturers of pig iron and raw steel and castings | | Manufacturers of steel castings | | Iron foundries and miscellaneous users | | Total, all types[1] | |
|---|---|---|---|---|---|---|---|---|
| | Scrap | Pig iron | Scrap | Pig iron | Scrap | Pig iron | Scrap | Pig iron |
| Blast furnace[2] | 2,481 | -- | -- | -- | -- | -- | 2,481 | -- |
| Basic oxygen process[3] | 15,339 | 44,515 | -- | -- | -- | -- | 15,339 | 44,515 |
| Open-hearth furnace | 2,411 | 4,737 | W | W | -- | -- | 2,411 | 4,737 |
| Electric furnace[3] | 32,252 | 5 | 1,965 | 68 | 4,411 | 430 | 38,628 | 503 |
| Cupola furnace | 20 | 73 | 110 | -- | 10,330 | 427 | 10,459 | 501 |
| Other (including air furnace)[4] | 698 | 37 | -- | -- | 477 | 19 | 1,175 | 56 |
| Direct castings[5] | -- | 468 | -- | -- | -- | 633 | -- | 1,101 |
| Total[1] | 53,201 | 49,833 | 2,075 | 68 | 15,217 | 1,510 | 70,493 | 51,411 |

W Withheld to avoid disclosing company proprietary data; included with "Electric furnace."

[1] Data may not add to totals shown because of independent rounding.

[2] Includes consumption in blast furnaces producing pig iron.

[3] Includes scrap and pig iron processed in metallurgical blast cupolas and used in oxygen converters.

[4] Includes vacuum melting furnaces and miscellaneous uses.

[5] Includes ingot molds and stools.

## Table 5.—Proportion of iron and steel scrap and pig iron used in furnaces in the United States in 1985

(Percent)

| Type of furnace | Scrap | Pig iron |
|---|---|---|
| Basic oxygen process | 25.6 | 74.4 |
| Open-hearth furnace | 33.7 | 66.3 |
| Electric furnace | 98.7 | 1.3 |
| Cupola furnace | 95.4 | 4.6 |
| Other (including air furnace) | 95.5 | 4.5 |

## Table 6.—Iron and steel scrap supply[1] available for consumption in 1985, by region and State

(Thousand short tons)

| Region and State | Receipts of Scrap: From brokers, dealers and other outside sources | Receipts of Scrap: From other own-company plants | Production of Home Scrap: Recirculating scrap resulting from current operations | Production of Home Scrap: Obsolete (includes ingot molds, stools, and scrap from old equipment, buildings, etc.) | Total new supply[2] | Shipments of scrap[3] | New supply available for consumption |
|---|---|---|---|---|---|---|---|
| New England and Middle Atlantic: | | | | | | | |
| Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island | 1,352 | 88 | 391 | 10 | 1,840 | 117 | 1,723 |
| Pennsylvania | 4,498 | 818 | 4,629 | 278 | 10,224 | 1,280 | 8,944 |
| Total[2] | 5,850 | 906 | 5,020 | 288 | 12,064 | 1,398 | 10,666 |
| North Central: | | | | | | | |
| Illinois | 3,916 | 995 | 2,239 | 72 | 7,221 | 175 | 7,047 |
| Indiana | 3,203 | 197 | 6,760 | 236 | 10,396 | 1,038 | 9,358 |
| Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska | 5,876 | 984 | 3,579 | 31 | 10,470 | 224 | 10,246 |
| Ohio | 4,897 | 1,235 | 4,690 | 207 | 11,029 | 1,193 | 9,837 |
| Wisconsin | 655 | 2 | 444 | -- | 1,100 | 7 | 1,093 |
| Total[2] | 18,546 | 3,413 | 17,711 | 546 | 40,217 | 2,636 | 37,580 |
| South Atlantic: | | | | | | | |
| Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia | 4,154 | 226 | 2,602 | 59 | 7,042 | 156 | 6,885 |
| South Central: | | | | | | | |
| Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas | 6,208 | 1,126 | 3,011 | 86 | 10,432 | 276 | 10,156 |
| Mountain and Pacific: | | | | | | | |
| Arizona, California, Colorado, Hawaii, Montana, Nevada, Oregon, Utah, Washington | 2,602 | 311 | 1,072 | 53 | 4,040 | 60 | 3,979 |
| Grand total[2] | 37,362 | 5,983 | 29,416 | 1,032 | 73,792 | 4,527 | 69,266 |

[1] New supply available for consumption is a net figure computed by adding production to receipts and deducting scrap shipped during the year. The plus or minus difference in stock levels at the beginning and end of the year is not taken into consideration.

[2] Data may not add to totals shown because of independent rounding.

[3] Includes scrap shipped, transferred, or otherwise disposed of during the year.

## Table 7.—U.S. consumption of iron and steel scrap and pig iron[1] in 1985, by region and State

(Thousand short tons)

| Region and State | Pig iron and steel ingots and castings | | Steel castings | | Iron foundries and miscellaneous users | | Total[2] | |
|---|---|---|---|---|---|---|---|---|
| | Scrap | Pig iron | Scrap | Pig iron | Scrap | Pig iron | Scrap | Pig iron |
| New England and Middle Atlantic: | | | | | | | | |
| Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island | 1,103 | (3) | 64 | 1 | 624 | 45 | 1,790 | 47 |
| Pennsylvania | 7,898 | 6,341 | 155 | 8 | 1,124 | 426 | 9,177 | 6,775 |
| Total | 9,001 | 6,341 | 219 | 9 | 1,748 | 471 | 10,967 | 6,822 |

See footnotes at end of table.

## Table 7.—U.S. consumption of iron and steel scrap and pig iron[1] in 1985, by region and State —Continued

(Thousand short tons)

| Region and State | Pig iron and steel ingots and castings |  | Steel castings |  | Iron foundries and miscellaneous users |  | Total[2] |  |
|---|---|---|---|---|---|---|---|---|
|  | Scrap | Pig iron | Scrap | Pig iron | Scrap | Pig iron | Scrap | Pig iron |
| North Central: |  |  |  |  |  |  |  |  |
| Illinois | 5,723 | 2,488 | 169 | (3) | 1,264 | 214 | 7,155 | 2,702 |
| Indiana | 8,644 | 15,926 | 159 | 42 | 791 | 48 | 9,593 | 16,016 |
| Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska | 5,676 | 4,640 | 389 | 1 | 4,193 | 518 | 10,258 | 5,159 |
| Ohio | 7,094 | 9,600 | 263 | 10 | 2,643 | 91 | 10,001 | 9,700 |
| Wisconsin | -- | -- | 129 | 1 | 971 | 50 | 1,101 | 51 |
| Total[2] | 27,137 | 32,654 | 1,108 | 54 | 9,862 | 921 | 38,108 | 33,629 |
| South Atlantic: |  |  |  |  |  |  |  |  |
| Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia | 5,614 | W | 27 | W | 1,274 | 31 | 6,915 | 31 |
| South Central: |  |  |  |  |  |  |  |  |
| Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas | 8,158 | [4]10,837 | 331 | [4]5 | 1,939 | 74 | 10,428 | [4]10,916 |
| Mountain and Pacific: |  |  |  |  |  |  |  |  |
| Arizona, California, Colorado, Hawaii, Montana, Nevada, Oregon, Utah, Washington | 3,291 | W | 389 | W | 394 | 11 | 4,075 | 11 |
| Grand total[2] | 53,201 | 49,833 | 2,075 | 68 | 15,217 | 1,510 | 70,493 | 51,411 |

W Withheld to avoid disclosing company proprietary data; included with "South Central" region.
[1] Includes molten pig iron used for ingot molds and direct castings.
[2] Data may not add to totals shown because of independent rounding.
[3] Less than 1/2 unit.
[4] Includes South Atlantic, Mountain and Pacific regions.

## Table 8.—U.S. consumer stocks of iron and steel scrap and pig iron, December 31, 1985, by region and State

(Thousand short tons)

| Region and State | Carbon steel (excludes rerolling rails) | Stainless steel | Alloy steel (excludes stainless) | Cast iron (includes borings) | Other grades of scrap | Total scrap stocks[1] | Pig iron stocks |
|---|---|---|---|---|---|---|---|
| New England and Middle Atlantic: |  |  |  |  |  |  |  |
| Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island | 126 | 20 | 32 | 29 | 3 | 210 | 4 |
| Pennsylvania | 653 | 42 | 124 | 119 | 48 | 985 | 100 |
| Total[1] | 779 | 62 | 155 | 147 | 50 | 1,194 | 104 |
| North Central: |  |  |  |  |  |  |  |
| Illinois | 380 | -- | 13 | 55 | 1 | 448 | 12 |
| Indiana | 330 | 1 | 14 | 132 | 2 | 479 | 18 |
| Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska | 488 | 1 | 7 | 104 | 16 | 615 | 27 |
| Ohio | 339 | 10 | 61 | 95 | 7 | 512 | 27 |
| Wisconsin | 9 | 2 | -- | 6 | (2) | 18 | 4 |
| Total[1] | 1,546 | 14 | 94 | 393 | 26 | 2,073 | 89 |

See footnotes at end of table.

## Table 8.—U.S. consumer stocks of iron and steel scrap and pig iron, December 31, 1985, by region and State —Continued

(Thousand short tons)

| Region and State | Carbon steel (excludes rerolling rails) | Stainless steel | Alloy steel (excludes stainless) | Cast iron (includes borings) | Other grades of scrap | Total scrap stocks[1] | Pig iron stocks |
|---|---|---|---|---|---|---|---|
| South Atlantic: | | | | | | | |
| Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia | 475 | 6 | 8 | 61 | 9 | 558 | 7 |
| South Central: | | | | | | | |
| Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas | 746 | 3 | 20 | 108 | 31 | 908 | 63 |
| Mountain and Pacific: | | | | | | | |
| Arizona, California, Colorado, Hawaii, Montana, Nevada, Oregon, Utah, Washington | 275 | -- | 23 | 69 | 2 | 370 | 3 |
| Grand total[1] | 3,822 | 85 | 301 | 777 | 118 | 5,104 | 266 |

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 1/2 unit.

## Table 9.—U.S. average monthly price and composite price for No. 1 heavy melting scrap in 1985

(Per long ton)

| Month | Chicago | Pittsburgh | Philadelphia | Composite price[1] |
|---|---|---|---|---|
| January | $78.86 | $86.48 | $80.00 | $81.78 |
| February | 82.16 | 88.32 | 80.00 | 83.49 |
| March | 84.76 | 91.19 | 81.43 | 85.75 |
| April | 79.59 | 83.05 | 80.57 | 82.07 |
| May | 68.00 | 72.68 | 73.82 | 71.50 |
| June | 62.00 | 69.50 | 68.25 | 66.58 |
| July | 64.24 | 72.62 | 68.29 | 68.38 |
| August | 73.00 | 77.00 | 74.00 | 74.66 |
| September | 72.00 | 74.20 | 74.00 | 73.40 |
| October | 71.87 | 73.50 | 71.52 | 72.29 |
| November | 69.00 | 69.50 | 71.00 | 69.83 |
| December | 69.17 | 72.12 | 71.00 | 70.76 |
| Average 1985 | 72.89 | 77.43 | 74.41 | 74.91 |
| Average 1984[r] | 83.12 | 92.71 | 87.92 | 87.91 |

[r] Revised.

[1] American Metal Market, composite price, Chicago, Pittsburgh, and Philadelphia, Feb. 7, 1986.

## Table 10.—U.S. exports[1] of iron and steel scrap, by country

(Thousand short tons and thousand dollars)

| Country | 1981 | | 1982 | | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| Canada | 737 | 52,463 | 307 | 21,006 | 539 | 39,717 | 779 | 59,521 | 446 | 38,445 |
| Italy | 34 | 2,407 | 12 | 2,972 | 65 | 4,395 | 306 | 27,038 | 307 | 30,250 |
| Japan | 1,191 | 117,724 | 1,530 | 145,083 | 2,600 | 218,337 | 2,680 | 264,857 | 2,110 | 199,135 |
| Korea, Republic of | 1,241 | 114,736 | 1,522 | 115,515 | 1,476 | 111,051 | 1,833 | 160,892 | 1,978 | 160,674 |
| Mexico | 896 | 102,329 | 380 | 33,822 | 419 | 36,017 | 484 | 47,663 | 597 | 57,535 |
| Spain | 434 | 34,570 | 868 | 61,616 | 356 | 22,734 | 608 | 55,228 | 910 | 72,312 |
| Taiwan | 374 | 59,874 | 352 | 57,213 | 499 | 75,638 | 405 | 54,515 | 414 | 45,163 |
| Turkey | 364 | 31,814 | 639 | 48,286 | 700 | 50,851 | 807 | 69,579 | 955 | 80,133 |
| Venezuela | 55 | 4,620 | 45 | 3,231 | 20 | 1,197 | 392 | 33,346 | 471 | 36,384 |
| Other | [r]1,090 | [r]118,106 | [r]1,150 | [r]121,559 | [r]846 | [r]76,785 | [r]1,204 | [r]145,341 | 1,760 | 198,153 |
| Total[2] | 6,415 | 638,644 | 6,804 | 610,302 | 7,520 | 636,723 | 9,498 | 917,981 | 9,950 | 918,186 |

[r] Revised.

[1] Excludes rerolling material and ships, boats, and other vessels for scrapping.

[2] Data may not add to totals shown because of independent rounding.

## Table 11.—U.S. exports and imports for consumption of iron and steel scrap, by class

(Thousand short tons and thousand dollars)

| Class | 1981 |  | 1982 |  | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| Exports: |  |  |  |  |  |  |  |  |  |  |
| No. 1 heavy melting scrap | 1,606 | 141,205 | 1,883 | 138,973 | 1,895 | 139,935 | 2,512 | 215,482 | 2,766 | 218,593 |
| No. 2 heavy melting scrap | 618 | 51,630 | 626 | 44,032 | 720 | 50,081 | 879 | 70,906 | 767 | 58,537 |
| No. 1 bundles | 41 | 3,476 | 115 | 8,619 | 206 | 16,486 | 77 | 8,258 | 185 | 17,172 |
| No. 2 bundles | 273 | 18,993 | 181 | 11,310 | 220 | 13,727 | 286 | 18,836 | 306 | 21,160 |
| Stainless steel scrap | 63 | 40,307 | 131 | 74,052 | 80 | 44,671 | 164 | 96,426 | 180 | 104,898 |
| Shredded steel scrap | 1,923 | 179,626 | 2,023 | 160,169 | 2,029 | 154,753 | 2,775 | 251,976 | 2,559 | 220,320 |
| Borings, shovelings, turnings | 486 | 24,757 | 577 | 28,923 | 532 | 28,277 | 800 | 49,664 | 875 | 56,314 |
| Other steel scrap[1] | 903 | 127,937 | 878 | 112,130 | 1,532 | 164,101 | 1,416 | 155,685 | 1,646 | 162,484 |
| Iron scrap | 501 | 50,714 | 389 | 32,096 | 306 | 24,692 | 590 | 50,748 | 666 | 58,707 |
| Total[2] | 6,415 | 638,644 | 6,804 | 610,302 | 7,520 | 636,723 | 9,498 | 917,981 | 9,950 | 918,186 |
| Ships, boats, other vessels (for scrapping) | 52 | 3,643 | 69 | 4,440 | 198 | 9,623 | 283 | 9,503 | 131 | 6,627 |
| Rerolling material | 57 | 10,831 | 53 | 7,969 | 34 | 4,194 | 58 | 10,918 | 110 | 15,604 |
| Total exports[2] | 6,524 | 653,118 | 6,925 | 622,711 | 7,752 | 650,540 | 9,840 | 938,402 | 10,191 | 940,416 |
| Imports for consumption: |  |  |  |  |  |  |  |  |  |  |
| Iron and steel scrap | 556 | 62,126 | 468 | 37,572 | 641 | 48,219 | 572 | 46,946 | 601 | 45,620 |

[1] Includes terneplate and tinplate.

[2] Data may not add to totals shown because of independent rounding.

## Table 12.—U.S. exports of rerolling material (scrap), by country

(Thousand short tons and thousand dollars)

| Country | 1981 |  | 1982 |  | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| China | -- | -- | -- | -- | -- | -- | -- | -- | 19 | 2,497 |
| Korea, Republic of | -- | -- | -- | -- | 5 | 462 | -- | -- | -- | -- |
| Mexico | 55 | 10,267 | 33 | 5,290 | 28 | 3,579 | 57 | 8,248 | 90 | 12,511 |
| Other | 2 | 564 | 20 | 2,679 | 1 | 153 | 1 | 2,670 | 1 | 596 |
| Total | 57 | 10,831 | 53 | 7,969 | 34 | 4,194 | 58 | 10,918 | 110 | 15,604 |

## Table 13.—U.S. imports for consumption of iron and steel scrap,[1] by country

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Austria | 55 | $175 | 96 | $306 |
| Belgium-Luxembourg | 63 | 49 | 502 | 653 |
| Canada | 532,241 | 41,866 | 562,032 | 37,242 |
| Germany, Federal Republic of | 2,141 | 131 | 1,978 | 524 |
| Japan | 3,157 | 419 | 6,626 | 1,162 |
| Mexico | 20,990 | 2,866 | 24,658 | 4,057 |
| Netherlands | 1 | (2) | 701 | 208 |
| Panama | 4,235 | 123 | 56 | 26 |
| Sweden | 750 | 104 | 2 | 1 |
| United Kingdom | 2,261 | 261 | 2,931 | 973 |
| Other | 6,115 | 952 | 1,672 | 466 |
| Total[3] | 572,010 | 46,946 | 601,254 | 45,620 |

[1] Includes tinplate and terneplate.

[2] Less than 1/2 unit.

[3] Data may not add to totals shown because of independent rounding.

## Table 14.—Iron and steel scrap consumption in selected countries[1]

(Thousand short tons)

| Country | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|
| North America: |  |  |  |  |  |
| Canada[2] [3] [4] [5] | 9,395 | 8,233 | 6,261 | 6,965 | [e]7,000 |
| United States[2] [5] [6] | 83,710 | 85,097 | 56,386 | 61,782 | 65,702 |
| Latin America:[7] |  |  |  |  |  |
| Argentina | 1,321 | 1,338 | 1,569 | 1,570 | 1,281 |
| Brazil | 7,130 | 6,052 | 5,625 | 6,137 | 6,971 |
| Chile | 209 | [e]210 | 146 | 209 | 237 |
| Colombia | 211 | [e]205 | 324 | 369 | 378 |
| Ecuador | 20 | [e]25 | 33 | 26 | 21 |
| Mexico | 3,425 | 3,618 | 3,332 | 2,383 | 3,181 |
| Peru | 224 | [e]180 | 120 | 186 | 343 |
| Uruguay | 24 | [e]20 | 34 | 56 | 53 |
| Venezuela | 1,068 | [e]1,090 | 1,027 | 457 | 1,292 |
| Central America, not further detailed | [r]164 | [r] [e]100 | 82 | 74 | 126 |
| Europe: |  |  |  |  |  |
| European Economic Community: |  |  |  |  |  |
| Belgium[2] | 4,065 | 4,133 | 4,566 | [5]3,480 | [5]3,880 |
| Denmark[8] | 894 | 758 | 690 | 644 | 718 |
| France | 8,748 | 8,040 | 7,076 | 7,197 | 7,135 |
| Germany, Federal Republic of[8] | 22,401 | 21,632 | 19,339 | 19,692 | 20,510 |
| Greece[e] | 310 | 300 | 300 | 275 | 300 |
| Ireland[8] | 3 | 41 | 76 | 174 | 208 |
| Italy[3] | [9]19,825 | 17,799 | 16,944 | 15,861 | [e]17,420 |
| Luxembourg | 1,738 | 1,458 | 1,450 | 1,508 | [e]1,850 |
| Netherlands | 2,025 | 1,961 | 1,594 | 1,607 | 1,797 |
| United Kingdom | 10,248 | 11,424 | 11,535 | [r]10,569 | 10,578 |
| European Free Trade Association: |  |  |  |  |  |
| Austria | 1,910 | 1,910 | 1,807 | [3]1,797 | [3]1,851 |
| Finland[3] | 848 | 807 | 758 | [10]780 | [e]831 |
| Norway[4] | 526 | [3]559 | [3]537 | [3]577 | [3]638 |
| Portugal | 564 | [r]486 | 522 | [e]575 | [e]600 |
| Sweden[2] [3] [5] | 2,835 | 2,924 | 3,145 | [e]3,395 | [e]3,500 |
| Switzerland | 992 | [9]948 | [9]915 | [e]915 | [e]915 |

See footnotes at end of table.

## Table 14.—Iron and steel scrap consumption in selected countries[1] —Continued

(Thousand short tons)

| Country | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|
| Europe —Continued | | | | | |
| Council for Mutual Economic Assistance: | | | | | |
| Bulgaria[e] | 860 | 830 | 830 | 820 | 850 |
| Czechoslovakia[2 3 5] | 8,884 | 8,244 | 8,186 | 8,665 | 8,365 |
| German Democratic Republic[2 3 4 5] | 5,833 | 5,816 | 5,649 | 5,682 | 5,779 |
| Hungary[2 3 5] | 2,528 | 2,425 | 2,446 | 2,445 | 2,705 |
| Poland | 11,817 | 9,598 | [r 3]8,983 | [r 3]9,796 | 9,630 |
| Romania[e] | 4,300 | 4,250 | 4,260 | 4,270 | 4,300 |
| U.S.S.R.[e] | 56,690 | 56,900 | [r]60,300 | [r]63,400 | 64,500 |
| Other: | | | | | |
| Spain | 9,974 | 9,933 | 10,042 | 10,795 | [e]11,100 |
| Yugoslavia | 2,287 | 2,324 | 2,245 | 2,434 | [e]2,500 |
| Africa: South Africa, Republic of[2] | [11]3,974 | [11]3,333 | [e]3,060 | [e]2,600 | [e]3,000 |
| Asia: | | | | | |
| China[e] | 9,400 | 9,000 | 9,400 | 10,100 | 10,900 |
| India[e] | 4,080 | 4,100 | 4,200 | 4,050 | 4,060 |
| Japan[5] | 48,291 | 44,616 | 42,832 | 44,269 | 47,934 |
| Korea, Republic of[e] | 2,200 | 2,700 | 3,300 | 3,350 | 3,600 |
| Taiwan[e 12] | 1,200 | 1,100 | 1,400 | 1,700 | 1,700 |
| Turkey | [e]1,900 | [9]1,764 | [e]1,900 | [e]2,300 | [e]2,500 |
| Oceania: | | | | | |
| Australia[e] | 2,470 | 2,480 | 2,070 | 1,820 | 2,050 |
| New Zealand[e] | 160 | 155 | 160 | 150 | 180 |
| Total | [r]361,681 | [r]350,916 | [r]317,456 | [r]327,906 | 344,969 |

[e] Estimated. [r] Revised.

[1] Unless otherwise specified, figures represent actual reported consumption of iron and steel scrap utilized in the production of pig iron, ferroalloys, crude steel, foundry products, and rerolled steel, as well as other unspecified uses in the steel industry and by other unspecified industries as reported by the United Nations Economic Commission for Europe in its Annual Bulletin of Steel Statistics for Europe 1984, v. 12, New York, 1985, 83 pp., which is the source of all reported data unless otherwise specified. All estimates are by the Bureau of Mines.

[2] Excludes scrap consumed by steel rerollers.

[3] Excludes scrap consumed in iron foundries.

[4] Excludes scrap consumed within the steel industry for purposes other than the manufacture of pig iron, ferroalloys, crude steel, foundry products, and rerolled steel (details on use not available).

[5] Excludes scrap consumed outside the steel industry.

[6] Bureau of Mines.

[7] Except where individually specified as an estimate or as being derived from another source, data are from Instituto Latino Americano del Fierro y el Acero. Statistical Yearbook of Steel Making and Iron Ore Mining in Latin America, 1984. Santiago, 1985, 220 pp. Source does not provide details on what is included; presumably figures include total steel industry ferrous scrap consumption but exclude scrap used outside the steel industry.

[8] Includes scrap used in production of steel casting in shipyards, but excludes scrap, if any, used in production of pig iron and that used in iron foundries.

[9] Organization for Economic Cooperation and Development. The Iron and Steel Industry in 1980, Paris, 1982, 40 pp.; The Iron and Steel Industry in 1981, Paris, 1983, 40 pp.; The Iron and Steel Industry in 1982, Paris, 1984, 52 pp; and The Iron and Steel Industry in 1983, Paris, 1985, 52 pp.

[10] Excludes consumption, if any, in the production of pig iron.

[11] Iron and Steel Statistics Bureau (United Kingdom). International Steel Statistics, Republic of South Africa, 1981, p. 4.

[12] Excludes a substantial tonnage derived from shipbreaking (possibly of the order of several million tons annually for electric-furnace-equipped steel mills).

## Table 15.—Iron and steel scrap exports, by selected countries[1]

(Thousand short tons)

| Continent, country group, and country | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|
| North America: | | | | | |
| Canada | 865 | 632 | [r]691 | [r]956 | 876 |
| United States[2] [3] | 11,254 | 6,472 | 6,857 | [r]7,634 | 9,498 |
| Latin America: | | | | | |
| Mexico[2] | 4 | 2 | 22 | 4 | [e]10 |
| Europe: | | | | | |
| European Economic Community: | | | | | |
| Belgium-Luxembourg | 592 | 637 | 549 | 752 | 853 |
| Denmark | 110 | 204 | 130 | 193 | 258 |
| France | 3,651 | 3,510 | 3,397 | 3,557 | 4,525 |
| Germany, Federal Republic of | 3,392 | 3,756 | 3,160 | 3,282 | 3,602 |
| Greece | (4) | 1 | 1 | 1 | 1 |
| Ireland | 93 | [r]81 | 65 | 23 | 47 |
| Italy | 9 | 25 | 19 | 20 | 21 |
| Netherlands | 1,316 | 1,380 | 1,300 | 1,678 | 1,851 |
| United Kingdom | 3,092 | 3,712 | 3,387 | 4,182 | 4,758 |
| European Free Trade Association: | | | | | |
| Austria | 14 | 14 | 10 | 14 | 23 |
| Finland | (4) | (4) | (4) | (4) | 11 |
| Iceland | 3 | 3 | 4 | [r]11 | [2]11 |
| Norway | 42 | 35 | 35 | 40 | 23 |
| Portugal | 6 | 6 | 10 | 11 | 10 |
| Sweden | 15 | 15 | 20 | 23 | 24 |
| Switzerland | 71 | 141 | 116 | [r]165 | 117 |
| Council for Mutual Economic Assistance: | | | | | |
| Bulgaria | 171 | 87 | 63 | 42 | 53 |
| Czechoslovakia[5] | 109 | 113 | [r]107 | 137 | [e]150 |
| German Democratic Republic[5] | 54 | 21 | [r]22 | 23 | [e]25 |
| Hungary | 34 | 35 | 58 | 55 | 87 |
| Poland[2] | 16 | [r]88 | [r]284 | 161 | 194 |
| Romania[5] | (4) | (4) | (4) | (4) | (4) |
| U.S.S.R.[2] | 2,756 | 2,681 | 2,859 | 3,715 | 3,756 |
| Other: | | | | | |
| Spain | 1 | 21 | 1 | 1 | 4 |
| Yugoslavia | 50 | [2]65 | 70 | 78 | 157 |
| Africa: | | | | | |
| Algeria[2] | 72 | 48 | 62 | 61 | [e]70 |
| Morocco[2] | 38 | 56 | 57 | 72 | [e]80 |
| South Africa, Republic of[5] | 7 | 2 | 4 | 51 | [e]50 |
| Asia: | | | | | |
| Brunei | (4) | 6 | 5 | 10 | [e]10 |
| China[5] | 11 | 161 | 108 | 40 | [e]100 |
| Cyprus | 6 | (4) | 8 | 9 | 15 |
| Hong Kong[2] | 302 | 371 | 327 | [r]363 | 331 |
| India[2] | 2 | 22 | [e]20 | [e]20 | [e]20 |
| Indonesia[2] | 1 | -- | (4) | 1 | 1 |
| Japan | 175 | 206 | 193 | 128 | 161 |
| Korea, North[5] | 2 | 8 | 15 | 7 | [e]10 |
| Korea, Republic of[2] | 10 | 28 | 155 | 314 | 149 |
| Kuwait | 69 | 27 | 20 | [e]20 | [e]20 |
| Malaysia[2] | 12 | 13 | 7 | [e]10 | [e]10 |
| Mongolia[5] | 22 | 24 | 26 | 24 | [e]25 |
| Philippines[2] | 2 | 2 | 2 | 1 | 1 |
| Saudi Arabia | 18 | 58 | 33 | [e]35 | [e]35 |
| Singapore[2] | 6 | 2 | 9 | 132 | 120 |
| Taiwan[2] | 14 | 141 | 443 | 308 | 223 |
| Thailand[2] | 1 | 2 | 9 | 2 | 4 |
| United Arab Emirates | 3 | 4 | 7 | [e]10 | [e]10 |
| Oceania: | | | | | |
| Australia[2] | [e]600 | 708 | 1,249 | 619 | 409 |
| New Zealand[2] | 49 | 3 | 3 | 3 | 4 |
| Total | [r]29,142 | [r]25,629 | [r]25,999 | [r]28,998 | 32,803 |

[e]Estimated. [r]Revised.

[1] Unless otherwise specified, source is United Nations Economic Commission for Europe. Annual Bulletin of Steel Statistics for Europe 1984, v. 12, New York, 1985, 83 pp.

[2] Official trade returns of subject country.

[3] Includes rerolling material.

[4] Less than 1/2 unit.

[5] Partial figure; compiled from import statistics of trading partner countries.

## Table 16.—Iron and steel scrap imports by selected countries[1]

(Thousand short tons)

| Continent, country group, and country | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|
| North America: | | | | | |
| Canada | 1,119 | 924 | 505 | [r]737 | [2]1,247 |
| United States[2] | 582 | 556 | 468 | 641 | 577 |
| Latin America: | | | | | |
| Argentina[2] | 2 | 2 | 2 | 8 | [e]10 |
| Brazil[2] | 24 | 8 | 8 | (3) | 34 |
| Chile | (3) | 5 | [e]10 | [e]10 | [e]10 |
| Colombia[2] | 14 | 33 | 30 | 51 | 48 |
| Cuba | [4]95 | [e]100 | [e]100 | [4]107 | [e]100 |
| Mexico[2] | 257 | 235 | [r]464 | 390 | [e]400 |
| Peru[2] | 36 | 40 | 18 | [e]20 | [e]20 |
| Venezuela[2] | 36 | 55 | 23 | 20 | [e]20 |
| Europe: | | | | | |
| European Economic Community: | | | | | |
| Belgium-Luxembourg | 947 | 1,054 | 978 | 1,152 | 1,843 |
| Denmark | 239 | 198 | 97 | 74 | 146 |
| France | 503 | 383 | 304 | 338 | 449 |
| Germany, Federal Republic of | 1,658 | 1,473 | 1,421 | [r]1,424 | 1,935 |
| Greece | 263 | 317 | 478 | [r]573 | 362 |
| Ireland | 9 | 4 | [r]3 | 77 | 97 |
| Italy | 8,168 | 6,107 | 6,141 | 4,901 | 6,047 |
| Netherlands | 170 | 262 | 244 | 401 | 527 |
| United Kingdom | 28 | 23 | 41 | 12 | 37 |
| European Free Trade Association: | | | | | |
| Austria | 158 | 187 | 420 | 241 | 400 |
| Finland | 117 | 68 | 56 | 41 | 36 |
| Norway | 58 | 26 | 4 | 17 | 14 |
| Portugal | 164 | 94 | 138 | [r]119 | 132 |
| Sweden | 84 | 272 | 583 | 496 | 925 |
| Switzerland | 151 | 125 | 118 | 162 | 301 |
| Council for Mutual Economic Assistance: | | | | | |
| Bulgaria | (3) | -- | -- | -- | -- |
| Czechoslovakia[4] | 62 | 278 | 81 | 173 | [e]200 |
| German Democratic Republic | 1,001 | 764 | 502 | 741 | 1,141 |
| Hungary | 4 | 159 | 15 | 31 | 22 |
| Poland | 250 | 58 | 6 | 6 | 8 |
| Romania | 62 | -- | -- | -- | -- |
| U.S.S.R.[5] | 23 | 24 | 27 | 24 | [e]25 |
| Other: | | | | | |
| Spain | 4,835 | 4,479 | 5,249 | 5,227 | 5,531 |
| Yugoslavia | 437 | [2]528 | 560 | 812 | 861 |
| Africa: | | | | | |
| Egypt[2] | 41 | 15 | 14 | [e]15 | [e]15 |
| Morocco | (3) | [2]2 | [2]3 | [2]3 | [e]3 |
| South Africa, Republic of[2] | 31 | 14 | 31 | 8 | [e]10 |
| Asia: | | | | | |
| China[4] | 2 | (3) | 3 | 2 | [e]3 |
| Hong Kong[2] | 103 | 104 | 71 | 30 | 31 |
| India[2] | 124 | 573 | [e]500 | [e]500 | [e]500 |
| Indonesia[2] | 43 | 69 | 250 | [r]284 | [e]300 |
| Japan | 3,291 | 1,974 | 2,232 | 4,306 | 4,429 |
| Korea, Republic of[2] | 2,130 | 2,546 | 1,994 | 2,090 | 2,294 |
| Malaysia[2] | 5 | 60 | 28 | [e]30 | 53 |
| Pakistan | 368 | 534 | 173 | 132 | 134 |
| Philippines[2] | 10 | 10 | 28 | (3) | 2 |
| Singapore[2] | 190 | 86 | 103 | 104 | 87 |
| Taiwan[2] | 1,358 | 971 | 718 | 811 | 637 |
| Thailand[2] | 373 | 460 | [r]430 | 707 | 545 |
| Turkey | 381 | 579 | 825 | 1,184 | 1,144 |
| Oceania: | | | | | |
| Australia[2] | 1 | 1 | [e]1 | [e]1 | [e]1 |
| New Zealand[2] | 69 | 5 | 6 | 3 | 3 |
| Total | 30,076 | 26,844 | [r]26,504 | [r]29,236 | 33,696 |

[e] Estimated. [r] Revised.

[1] Unless otherwise specified, source is United Nations Economic Commission for Europe. Annual Bulletin of Steel Statistics for Europe 1984, v. 12, New York, 1985, 83 pp.

[2] Official trade returns of subject country.

[3] Less than 1/2 unit.

[4] Partial figures; compiled from export statistics of trading partner countries.

[5] Partial figure; compiled from incomplete returns of subject country and export statistics of trading partner countries.

# Kyanite and Related Materials

## By Michael J. Potter[1]

Kyanite, andalusite, and sillimanite are anhydrous aluminum silicate minerals that are alike in both composition and use patterns and have the same chemical formula, $Al_2O_3 \cdot SiO_2$. When these minerals are calcined at approximately 2,900° F, they are converted into mullite. Related materials include synthetic mullite, dumortierite, and topaz, also classified as aluminum silicates, although the last two additionally contain substantial proportions of boron and fluorine, respectively. All of these kyanite-group substances can serve as raw materials for manufacturing special high-performance, high-alumina refractories, but there has been no record in recent years of either dumortierite or topaz being used for this purpose in the United States.

Although published statistics were incomplete, France, India, the Republic of South Africa, and the United States appeared to be the leading world producers of kyanite-group minerals. The U.S.S.R. and perhaps a few other industrialized nations also were presumed to produce significant quantities of these materials.

U.S. kyanite output in 1985 was estimated to be approximately the same as that of 1984. Major end uses of kyanite, mullite, and synthetic mullite were in refractories for the ferrous and nonferrous metals industries, where production generally remained flat in 1985.

**Domestic Data Coverage.**—Domestic production data for kyanite and synthetic mullite are developed by the Bureau of Mines by means of two separate, voluntary, domestic surveys. In the kyanite survey, of the three active mines canvassed, none responded. These mines were operated by two companies. An estimate of total production was made by the Bureau of Mines using last reported production levels adjusted by the trend of the minerals economy.

In the synthetic mullite survey, of the five canvassed operations, three, or 60%, responded and accounted for 12% of the total production data shown in table 1. The percentage of production that was estimated, 88%, was arrived at by using last reported production levels adjusted by the trend of the minerals economy.

**Legislation and Government Programs.**—The allowable depletion rates for kyanite, established by the Tax Reform Act of 1969 and unchanged through 1985, were 22% for domestic production and 14% for foreign operations.

## DOMESTIC PRODUCTION

Kyanite was produced in the United States at three open pit mines, two in Virginia and one in Georgia. Kyanite Mining Corp. operated the Willis Mountain and East Ridge Mines in Buckingham County, VA. Pasco Mining Inc. operated the Graves Mountain Mine in Lincoln County, GA.

There are three types of synthetic mullite. Fused synthetic mullite is made by melting Bayer process alumina and silica, or bauxite and kaolin in an electric furnace at about 3,450° F. High-temperature sintered synthetic mullite is prepared by sintering mixtures of alumina and kaolin, bauxite and kaolin, or alumina, kaolin, and kyanite above 3,180° F. Low-temperature sintered synthetic mullite is made by sintering siliceous bauxite or mixtures of bauxite and kaolin above 2,820° F.

Output of synthetic mullite in 1985 was estimated to be largely of the high-temperature sintered variety, and the two producers of this material were believed to be C-E Minerals Inc. at Americus, GA, and Harbison-Walker Refractories at Eufaula, AL. Electric-furnace-fused mullite was produced by Sohio Electro Minerals Co. at Niagara Falls, NY.

Table 1.—U.S. production of synthetic mullite

| Year | Quantity (short tons) | Value (thousands) |
|---|---|---|
| 1981 | 42,000 | $9,050 |
| 1982 | 27,000 | 5,950 |
| 1983$^e$ | 23,000 | 4,700 |
| 1984$^e$ | 27,000 | 5,300 |
| 1985$^e$ | 27,000 | 5,450 |

$^e$Estimated.

## CONSUMPTION AND USES

Kyanite and related materials were consumed mostly in the manufacture of high-alumina or mullite-class refractories and in lesser quantities as ingredients in ceramic compositions. U.S. kyanite, already ground to minus 35 mesh as required by the flotation process used in its separation and recovery, was marketed either in this raw form or, after heat treatment, as mullite, sometimes further reduced in particle size before use. In the 35- to 48-mesh range, kyanite was used mostly in monolithic refractory applications such as high-temperature mortars or cements, ramming mixes, and castable refractories, or with clays and other ingredients in refractory compositions for making kiln furniture, insulating brick, firebrick, and a wide variety of other articles. More finely ground material, minus 200 mesh, was used in body mixes for sanitary porcelains, wall tile, investment-casting molds, and miscellaneous special-purpose ceramics.

## PRICES

Engineering and Mining Journal, December 1985, listed prices for raw kyanite, f.o.b. Georgia, ranging from $92 to $144 per short ton for bulk shipments and $9 more per ton for bagged material. These prices were unchanged from those of 1984.

Prices in 1985, in British pounds, from Industrial Minerals (London) were the same as those of 1984. The price increases in U.S. dollars of 12% in table 2 reflect a corresponding increase in the value of the British pound against the U.S. dollar.[3]

Table 2.—Prices of kyanite and related materials

(Dollars per short ton)

| | 1984 | 1985 |
|---|---|---|
| Andalusite, Transvaal, 52% to 54% $Al_2O_3$, bulk, c.i.f. main European port | 79 | 89 |
| Andalusite, Transvaal, 60% $Al_2O_3$, c.i.f. main European port | 102 | 114 |
| Sillimanite, South African, 70% $Al_2O_3$, bags, c.i.f. main European port | 215 | 241 |
| U.S. kyanite, 59% to 62% $Al_2O_3$, 35-325 Tyler mesh, raw and/or calcined, 18-ton lots, c.i.f. main European port | 102-176 | 114-197 |
| U.S. kyanite, f.o.b. plant, carlots: | | |
| Calcined | 123-172 | 123-172 |
| Raw | 70-137 | 70-137 |

Source: Industrial Minerals (London). No. 219, Dec. 1985, p. 101.

## FOREIGN TRADE

An estimated one-third of U.S. production of kyanite- and mullite- containing materials was exported, with a substantial quantity going to the Federal Republic of Germany. Based on data from a non-Government source, imports of andalusite in 1985 were insignificant compared with those of 1984.

## WORLD REVIEW

During 1984, the last year for which information was available, the European refractories industry experienced difficulty in obtaining enough andalusite to satisfy its requirements. This was especially true with respect to ladle refractories. The shortage was largely due to the shutdown of two South African operations and a brief shutdown of the one French producer. However, the situation was expected to improve when new facilities in the two countries came on stream.

**France.**—Output of andalusite, which has been second only to that of the Republic of South Africa, was 46,300 short tons in 1983 and 57,300 tons in 1984. The sole producer, Denain Anzin Mineraux, planned to add a new plant to its two existing facilities in mid-1985, which could raise output to at least 70,000 tons per year. Exports in recent years have been largely to the Federal Republic of Germany, Italy, and the United Kingdom. About 20% of French output has been consumed internally.[3]

**South Africa, Republic of.**—Weedons Minerals (Pty.) Ltd. has been the largest single producer of andalusite in the world, with annual output of approximately 100,000 to 110,000 tons. The company had three processing plants in operation with a fourth being planned, which would presumably raise its production to 130,000 tons per year. Rand London Andalusite Ltd. was producing approximately 3,860 tons per month of andalusite, with new plant facilities scheduled to become operational in 1985. Export markets for Rand London were Australia, Europe, Israel, Japan, and the United States.

Verref Mining (Pty.) Ltd. has an andalusite capacity of 55,000 tons per year; material was marketed worldwide to refractory manufacturers, with Italy being a significant consumer. Hoogeneog Andalusite (Pty.) Ltd. planned to restart production in the near future. A newly installed processing plant was expected to bring production capacity to 22,000 tons per year. When production resumes, 80% of the output is expected to be exported to European markets.[4]

**Sweden.**—Svenska Kyanite AB, a new kyanite joint venture between Svenska Forshammar AB and Ulf Juval AB, was put into operation in May. The ore deposit contains an average of 30% kyanite, and proven reserves were put at 5 million tons. Beneficiation consists of crushing; grinding; flotation to separate quartz and kyanite; high-intensity magnetic separation to reduce the iron content; and filtration, drying, and packing of the kyanite product. The processing plant capacity was to be approximately 30,000 tons per year of product. The major market was to be the European refractories industry.[5] The high-intensity magnetic separator uses conventional permanent magnets but is as powerful as some electromagnetic wet, high-intensity separators.[6]

**United Kingdom.**—Imports of kyanite-group minerals in 1984 totaled 58,100 tons; principal countries of origin and percentages supplied were the Republic of South Africa, 48%; France, 26%; and the United States, 18%.[7]

### Table 3.—Kyanite: World production, by country[1]

(Short tons)

| Country[2] and commodity | 1981 | 1982 | 1983 | 1984$^{p}$ | 1985$^{e}$ |
|---|---|---|---|---|---|
| Australia: Sillimanite[3] | 365 | 863 | 133 | $^{r}$ $^{e}$660 | 550 |
| Brazil: Kyanite | 1,753 | 466 | 473 | $^{r}$ $^{e}$550 | 550 |
| China: Unspecified$^{e}$ | 2,800 | 2,800 | 2,800 | 2,800 | 2,800 |
| France: Andalusite | $^{e}$33,100 | $^{r}$46,300 | 46,300 | 57,300 | 55,100 |
| India: | | | | | |
| Andalusite | 161 | 591 | 2,836 | $^{e}$3,000 | 3,000 |
| Kyanite | 42,200 | 37,425 | 42,226 | 40,812 | 37,500 |
| Sillimanite | 11,303 | 14,403 | 8,739 | 14,746 | 14,300 |
| Kenya: Kyanite | -- | -- | 6,004 | 1,102 | 1,100 |
| Korea, Republic of: Andalusite | 99 | $^{r}$36 | 319 | 230 | 220 |
| South Africa, Republic of: | | | | | |
| Andalusite | 199,818 | 171,655 | 128,503 | 157,967 | 205,000 |
| Sillimanite | 17,090 | 11,089 | 898 | 1,445 | 1,600 |
| Spain: Andalusite | 6,780 | 5,627 | 4,945 | 3,307 | 3,900 |
| United States: | | | | | |
| Kyanite | W | W | W | W | W |
| Synthetic mullite | 42,000 | 27,000 | $^{e}$23,000 | $^{e}$27,000 | 27,000 |
| Zimbabwe: Kyanite | 959 | 2,433 | ([4]) | ([4]) | -- |

$^{e}$Estimated. $^{p}$Preliminary. $^{r}$Revised. W Withheld to avoid disclosing company proprietary data.

[1] Owing to incomplete reporting, this table has not been totaled. Table includes data available through Apr. 8, 1986.

[2] In addition to the countries listed, a number of other nations produce kyanite and related materials, but output is not reported quantitatively, and no reliable basis is available for estimation of output levels.

[3] In addition, sillimanite clay (also called kaolinized sillimanite) is produced, but output is not reported quantitatively, and available information is inadequate for the formulation of reliable estimates of output levels.

[4] Revised to zero.

## TECHNOLOGY

Piedmont Minerals Co. Inc. in North Carolina investigated the possibility of producing an andalusite product from its pyrophyllite-andalusite material. Pilot plant work yielded a product containing over 90% andalusite with an alumina content approaching 60%. Processing steps included fine grinding, heavy-media separation, and flotation. Further work on processing and marketing of the product would have to be carried out before any commercial production. The company can currently produce an andalusite-pyrophyllite product containing 50% to 55% andalusite that is used in refractories.[8]

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[1] Physical scientist, Division of Industrial Minerals.

[2] Where necessary, values have been converted from pounds sterling (£) per metric ton to U.S. dollars per short ton at the rate of £1.00=US$1.40 for 1985.

[3] Industrial Minerals (London). Sillimanite Minerals—Europe Places Demands on Andalusite. No. 208, Jan. 1985, pp. 45-46, 62.

[4] Pages 43-45 of work cited in footnote 3.

[5] Industrial Minerals (London). Svenska Kyanite Start-Up. No. 211, Apr. 1985, p. 13.

[6] Mining Journal (London). High Force Magnetic Separator. V. 304, No. 7819, June 28, 1985, p. 461.

[7] Industrial Minerals (London). United Kingdom Industrial Mineral Statistics. No. 211, Apr. 1985, p. 85.

[8] Dickson, T. North American Pyrophyllite-Ceramics Leading the Way. Ind. Miner. (London), No. 218, Nov. 1985, p. 57.

# Lead

## By William D. Woodbury[1]

Domestic mine output of recoverable lead increased by over 90,000 metric tons in 1985, but was the second lowest production since 1968. Primary refinery output also increased by over 90,000 tons, and although it too was the second lowest since 1968, total refined metal output, including that from secondary sources, was the highest since 1982. Net imports of refined metal for consumption were 50,000 tons less than those of 1984, but were still over 100,000 tons. Total net imports of contained lead in all forms, including scrap, declined significantly, as reported consumption declined by nearly 60,000 tons. The storage battery sector had a good year for the second year in a row and utilized almost three-quarters of the total demand for refined lead. The overall dropoff in domestic demand, in concert with the general worldwide overproduction of lead associated with relatively high levels of silver and zinc mining, resulted in the average U.S. producer sales price declining to its lowest level since 1973.

**Table 1.—Salient lead statistics**

(Metric tons unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production: | | | | | |
| Domestic ores, recoverable lead content | 445,535 | 512,516 | [r]449,295 | [r]322,677 | 413,955 |
| Value thousands | $358,821 | $288,579 | [r]$214,745 | [r]$181,745 | $174,008 |
| Primary lead (refined): | | | | | |
| From domestic ores and base bullion | 440,238 | 459,865 | 459,328 | 330,168 | 416,091 |
| From foreign ores and base bullion | 55,085 | 52,295 | 55,227 | 65,409 | 71,353 |
| Antimonial lead (primary lead content) | 3,008 | 4,622 | W | W | W |
| Secondary lead (lead content) | 641,105 | 571,276 | 503,501 | [r]633,374 | 594,186 |
| Exports (lead content): | | | | | |
| Lead ore and concentrates | 33,043 | 29,104 | 20,119 | 11,858 | 9,987 |
| Lead materials excluding scrap | 23,320 | 55,629 | 24,351 | 16,563 | 87,320 |
| Imports, general: | | | | | |
| Lead in ore and concentrates | 58,545 | 35,807 | 47,516 | 68,870 | 42,665 |
| Lead in base bullion | 449 | 19 | 53 | 43 | 760 |
| Lead in pigs, bars, reclaimed scrap | 107,185 | 99,587 | [1]179,485 | 167,868 | 136,697 |
| Stocks, Dec. 31 (lead content): | | | | | |
| At primary smelters and refineries | 140,207 | 125,537 | 106,661 | 135,079 | 127,950 |
| At consumers and secondary smelters | 123,216 | 97,209 | 100,771 | [r]97,077 | 93,130 |
| Consumption of metal, primary and secondary | 1,167,101 | 1,075,408 | 1,148,487 | 1,207,033 | 1,148,298 |
| Price: Common lead, average, cents per pound[2] | 36.53 | 25.54 | 21.68 | 25.55 | 19.07 |
| World: | | | | | |
| Production: | | | | | |
| Mine thousand metric tons | [r]3,365.5 | [r]3,422.5 | 3,358.6 | [p]3,255.8 | [e]3,391.7 |
| Refinery[3] do | [r]3,118.8 | [r]3,181.1 | 3,236.1 | [p]3,156.7 | [e]3,295.5 |
| Secondary refinery do | [r]2,211.3 | [r]2,038.9 | 2,021.6 | [p]2,266.8 | [e]2,178.1 |
| Price: London Metal Exchange, pure lead, cash average, cents per pound | 33.30 | 24.66 | 19.27 | 20.12 | 17.84 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Includes Bureau of Mines estimate of 42,000 metric tons of pigs and bars (lead content) of U.S. brands returned from the London Metal Exchange.

[2]Metals Week. Transactions on a delivered basis.

[3]Primary metal production only. Includes secondary metal production where inseparably included in country total.

World production of refined lead, including secondary, was estimated to have increased by 50,000 tons over that of 1984, and to have exceeded total world demand, which was 20,000 tons less than that of 1984, by 10,000 tons. That resulted in a buildup of metal stocks during 1985. Recoverable world mine production, which represented 60% of demand, was estimated to have increased by 136,000 tons from that of 1984. Despite depressed world prices for lead, 80,000 tons of net additional mine capacity was brought on-stream in 1985, mostly through new zinc and/or silver operations. The London Metal Exchange (LME) cash price for the year averaged only 1.2 cents per pound less than that in the United States, not generally favorable to domestic importers, and at 17.8 cents per pound was the lowest since 1972 (13.7 cents).

In the United States, a Federal regulation lowering the permissible amount of lead contained in gasoline additives by over 50% became effective in midyear. Austria banned the sale of leaded regular gasoline effective October 1, 1985, and the European Economic Community issued a directive in March requiring all member countries to ensure the availability and balanced distribution of unleaded gasoline by October 1, 1989. At the beginning of 1985, Austria, Denmark, the Federal Republic of Germany, Norway, Sweden, and Switzerland enforced a limit of 0.57 gram per gallon for all leaded gasoline. Finland enforced this limit on regular grade only, but was to extend it to all grades in January 1986. At yearend, the Environmental Protection Agency (EPA) in the United States was considering an outright ban on all lead in gasoline by 1988.

**Domestic Data Coverage.**—Domestic data for lead are developed by the Bureau of Mines from five voluntary surveys of U.S. operations. Typical of these are the combined monthly and annual secondary consumer surveys. Of the 297 plants to which a consumer survey request was sent, 94% responded, representing 99% of the total lead consumption shown in tables 1, 12, 13, 14, and 15. Of the 68 plants to which a secondary smelter production survey request was sent, 84% responded, representing 92% of the total refinery production of secondary lead recovered from scrap shown in tables 1, 10, and 11. Production and consumption for the nonrespondents were estimated using reported prior year levels adjusted by general industry trends.

**Legislation and Government Programs.**—The final phase of EPA's plan, announced in August 1984, to limit the permissible amount of lead in gasoline to 0.1 gram per gallon by January 1, 1988, was moved up to January 1, 1986, and an interim standard of 0.5 gram per gallon went into effect on July 1, 1985. In September, the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund) expired, but reauthorization bills had passed both houses of Congress at yearend. Although lead metal was added to the list of potentially hazardous materials to be taxed, a final revenue scheme was not developed by House and Senate Conferees, and no legislation was enacted at yearend. The Senate bill called for using the existing tax rates for petrochemical feedstocks and crude oil, plus an additional manufacturers' (producers') tax on other hazardous materials. The House bill raised the existing feedstock tax rates and set a tax on hazardous waste generated but not on the specific volume of toxic substances per se in the waste. Of most concern to the lead producers by yearend, however, was that the EPA was considering lowering the National Ambient Air-Quality Standard for lead from 1.5 micrograms per cubic meter to 0.5 microgram per cubic meter.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict that would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, lead would be categorized in both tier I and tier II; the goal would be 272,156 tons of lead metal equivalent in tier II, but no goal had been set for tier I at yearend. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984. During 1985, the National Defense Stockpile inventory remained at 545,000 tons of lead metal, about 55% of the current authorized goal.

## DOMESTIC PRODUCTION

### MINE PRODUCTION

Domestic mine production of recoverable lead was significantly higher than that of 1984, which was strike-affected. However, the total was the second lowest since 1968, 1 year before the Viburnum Trend operations in Missouri came fully on-stream. Higher production was not attained because the producers reportedly were fearful of building stocks in the face of the realized decrease in demand that was generally forecast for 1985. Seven Missouri lead mines accounted for about 90% of total domestic production, and together with the lead-producing mines in Colorado, Idaho, Montana, and New York accounted for almost all of the U.S. mine output. Some byproduct lead also was recovered from mining in five other States during the year.

According to AMAX Inc.'s annual report, the Buick Mine in Iron County, MO, equally owned by them as operator and Homestake Mining Co., continued to be the Nation's largest single lead-producing unit, milling 2.07 million tons of ore at an average grade of 6.9% lead, which yielded 137,500 tons of lead in concentrates. The average grade of hoisted ore dropped 1.2% from that of 1984 and was the lowest since 1981. Estimated proven and probable ore reserves of the mine at yearend were 18 million tons at an average grade of 8.0% lead, a decrease of 377,000 tons of contained lead compared with that of yearend 1984 owing to a revised mining plan.

The second largest producing lead mine was the Magmont Mine, in Iron County, MO, jointly owned by Cominco American Incorporated and Dresser Industries Inc. According to Cominco Ltd.'s annual report, a record high 1.04 million tons of ore was milled at an average grade of 7.51% lead, which yielded 100,400 tons of concentrates at an average grade of 73.3% lead. The record high production was attributed to replacement of the original flotation cells, installed in 1968, in the mill's lead flotation circuit with new ones of higher volume. Over 40% of Magmont's total ore production was extracted from Magmont West, which opened in late 1983. Measured and indicated ore reserves at yearend were 6.26 million tons at an average grade of 6.5% lead, 900,000 tons less than that of yearend 1984. Cominco's share of the Magmont Mine's lead production was purchased by ASARCO Incorporated's lead smelter-refinery at Glover, MO, and Dresser's share was tolled by Asarco.

The St. Joe Lead Co. Div. of St. Joe Minerals Corp., Clayton, MO, operated two mine and mill complexes involving four mines in southeastern Missouri on the Viburnum Trend in 1985. St. Joe was the largest U.S. lead mine producer during the year, accounting for about 37% of total domestic production, hoisting 3.2 million tons of ore with an average grade of 5.08% lead, according to parent Fluor Corp.'s annual Securities and Exchange (SEC) Form 10-K covering the fiscal year ending October 31, 1985. The four Missouri mines plus the Balmat zinc mine in New York produced 156,750 tons of lead in concentrates out of an estimated 427,000-ton U.S. total. St. Joe's mine capacity was estimated by the Bureau of Mines to be about 42% of that for the United States in 1985, and its mines had proven published reserves in Missouri on October 31 of 56.8 million tons grading approximately 5% lead, down about 500,000 tons from that reported on October 31, 1984. Development of the Viburnum No. 35 Mine, renamed the Casteel Mine in December, was completed during the year at a total cost of approximately $31.5 million, including mill expansion. St. Joe's Brushy Creek unit in Missouri did not operate during the year.

Approximately 60% of the ore contained in St. Joe's lead ore bodies is situated on properties held under Federal mineral leases for terms of 10 to 20 years for which St. Joe pays a royalty fee of 5% of the gross value of concentrates produced.

Hecla Mining Co.'s annual report stated that its Lucky Friday Mine in Shoshone County, ID, produced at record high capacity during the year and milled 251,124 tons of silver ore, which yielded a record high 31,560 tons of refined lead, an increase of 3,450 tons, or 11%, over the previous record high set in 1984. The concentrates were smelted at Asarco's East Helena, MT, plant. The increase was attributed to a 20% increase in labor productivity owing to equipment upgrading and more mechanization, and testing of an advanced mechanized mining method was begun. Proven and probable ore reserves at Lucky Friday at yearend were 608,000 tons containing 11.9%

lead and 16.6 troy ounces of silver per ton, a slight decrease in contained lead from yearend 1984.

Development work at Asarco's West Fork Mine in Reynolds County, MO, was completed during the year, and production was scaled up, starting with completion of the underground crushing system in September, to reach about 40% of capacity by yearend. The company did not plan to increase the level of production, however, until lead prices improved significantly. About 3,500 tons of lead in concentrates was produced, compared with 6,100 tons at the Leadville Mine in Colorado, an Asarco-operated 50% equity venture, according to the company's annual report. West Fork's proven and probable ore reserves at yearend were estimated to be 13.5 million tons grading 5.5% lead, and the mine's full production capacity was estimated to be 46,000 tons of lead in concentrates per year from a mill throughput of 3,450 tons of ore per day, according to Asarco.

### SMELTER AND REFINERY PRODUCTION

**Primary.**—In the fiscal year ending October 31, the St. Joe smelter-refinery at Herculaneum, MO, the Nation's largest, produced 161,760 tons of refined lead, an increase of over 27,000 tons from that reported for 1984 in parent Fluor's annual SEC Form 10-K. However, the plant was closed for the full month of July for routine maintenance and inventory adjustment. A strike was averted in April, at the last moment, and a new pact was signed by the Teamsters Union covering the 2 years until April 30, 1987.

According to Homestake's annual report, the AMAX-Homestake smelter-refinery at Boss, MO, produced 119,750 tons of refined lead from their Buick Mine mill production and stocks, an increase of about 15,000 tons over output in strike-affected 1984, and only about 10,000 tons below 1983's record. The plant, however, was shut down from October 16 to December 4 in order to compensate for the decreased lead concentrate production at Buick.

Asarco reported that its three smelters, one each at East Helena, MT, El Paso, TX, and Glover, MO, produced 202,120 tons of lead bullion, an increase of 17,400 tons over output in strike-affected 1984. Asarco's two refineries at Omaha, NE, and Glover, MO, produced 204,840 tons of refined lead metal, an increase of 29,400 tons from that of 1984. The El Paso and East Helena smelters shipped their bullion to Omaha, but operations were suspended indefinitely at El Paso at the end of August owing to a lack of dependable supply of foreign concentrates. Feed stocks from Australia, Canada, and Peru did not materialize in 1985, apparently owing to depressed world prices resulting from oversupply.

The U.S. primary industry produced refined lead at 82% of capacity for the year.

**Secondary.**—The U.S. secondary industry at yearend consisted essentially of 23 companies, which operated 30 plants with refined metal capacities ranging from 5,000 to 80,000 tons per year and which represented 98% of total production. There were also 38 small producers with annual capacities of 1,000 tons or less, which produced specialty alloys, including solders and specialized batteries. During the year, about 250,000 tons of capacity was closed, most permanently, including one plant of 68,000-ton capacity, which had filed for bankruptcy protection in 1984. At yearend, nominal engineered capacity stood at about 800,000 tons compared with about 1,300,000 tons at the end of 1980. However, effective operating capacity was only about 700,000 tons. As a result, the industry operated at 74% of nominal capacity for the year, compared with a revised estimate of about 60% for 1984. Taracorp Inc., which had been 1 of the top 10 producers, and which had filed for bankruptcy protection on October 1, 1982, successfully reestablished itself on July 31, 1985, primarily as a consumer of lead for lead products.

## CONSUMPTION AND USES

Despite reported increases in the consumption of lead in traditional areas such as ammunition, cable covering, and casting metals in transportation equipment, overall consumption declined by almost 60,000 tons in 1985, compared with that of 1984. This primarily was attributed to about 25,000 tons less demand by the battery manufacturers, and a decline of over 33,000 tons, or about 42%, in the use of lead for gasoline additives. The use of lead in solder declined for the seventh consecutive year, primarily in applications involving potable water supply systems and food containers. Lead-based paint and ceramic product applications also continued to decline.

According to Battery Council International statistics of domestic shipments plus units exported, production of automotive batteries, the largest specific end use of lead, was only about 304,500 units less than that of 1984; there were 357,000 less units exported in 1985. However, during the year there was a significant reduction of estimated materials in process inventories, which were estimated to represent about 65,000 tons of lead in grids and oxides in battery plants at the end of 1984, and this reduced the 1985 demand. Conversely, the Bureau of Mines estimated that the consumption of lead for grids and oxides in industrial and traction batteries during 1985 increased by over 40% to 145,800 tons. The total use of lead to manufacture each automotive battery was estimated by the Bureau of Mines to be 20.6 pounds per unit, the same as in 1984. This was attributed to the relatively high volume of larger cars and trucks in the original equipment market, which has arrested the trend toward downsizing of batteries in recent years. Exports of automotive batteries totaled 2,233,000 units. The use of lead for storage batteries of all types in the United States reached a record high 73% of the total lead consumed for all products. The use in the industrial and traction battery sector attained a record high 17% of that for all lead-acid batteries. The latter has been the greatest growth sector in lead consumption since 1982, more than doubling in 3 years, primarily for uninterruptible power supply (UPS) systems.

## STOCKS

Soft lead stocks at domestic primary refineries increased 36,000 tons during 1985, despite 50,000 tons less net imports for consumption of pig lead than in 1984. This was attributed to the increase of over 90,000 tons in primary refinery production, from which concentrate stocks were reduced by over 40,000 tons, and to the overall decline in domestic consumption. Refined pig lead stocks held by secondary producers and consumers were down only slightly at yearend, compared with those of yearend 1984. Total stocks of contained lead in all forms, excluding scrap, held by all domestic producers and consumers at yearend, were down only 11,000 tons, or 5%.

Stocks of lead and antimonial lead metal in the market economy countries reporting to the International Lead and Zinc Study Group (ILZSG) were approximately 470,000 tons at yearend, about 9% of current total world demand, and 41,000 tons higher than at yearend 1984.[3] At yearend, stocks in LME warehouses totaled 61,000 tons, an increase of 20,000 tons over those of yearend 1984.

## PRICES

The U.S. producer price quotations for lead published in Metals Week moved gradually downward from a range of 20 to 23 cents per pound in the last 2 weeks of 1984, to 17 to 22 cents per pound at the end of the first week of March 1985, which represented the widest spread of the year. The average of the week ending March 15 of weighted transactions was 17.1 cents per pound, the lowest of the year. From that point, the range gradually expanded and narrowed during the remainder of the normal slack buying season to 18.5 to 21 cents per pound on July 1, the accepted beginning of the ordering season for late summer-early fall deliveries to the battery manufacturers. Summer quotations in Metals Week generally stayed within that range but narrowed and lowered further on September 10 to 18.5 to 20 cents per pound, as significant anticipated seasonal ordering increases apparently did not materialize. Prices generally stayed in that range through the remainder of the year. The monthly weighted average transactions were within 0.2 cent of 19 cents per pound for every month of the year except for a low of 17.7 cents for March and a high of 19.9 cents for April. March's U.S. average price was the lowest since December 1973 (17.7 cents), and the year's average of 19.1 cents per pound also was the lowest since 1973 (16.3 cents). In constant dollars it was the lowest of the century.

On the LME the highest monthly average cash price for the year was reached in January, at slightly over 19 cents per pound. That was the narrowest spread against the U.S. producers' price, only 0.06 cent, since February 1975 when LME prices were higher than those of the United States. The LME price then dropped steadily through March, and the average for that month of just under 16 cents per pound was the lowest since February 1976 (15.8 cents). The price then rebounded steadily, reaching 19.2 cents for the last week of August, before declining steadily to 17.3 cents for the last week of the year. The LME's average cash price for the year of 17.8 cents per pound was the lowest since 1972 (13.7 cents), and the average spread for the year with the U.S. producers' price of 1.23 cents per pound was the narrowest since 1980, when it was 1.25 cents.

The domestic prices for lead oxides were based on the selling price for pig lead in a given period plus conversion charges. However, premium adjustments were also made by individual producers to reflect differences in manufacturing techniques, freight considerations, quality requirements, and other factors. The average total premium for carload lots, f.o.b. plant, exclusive of container, for litharge was just over 9 cents per pound above the average pig lead price according to shipment values reported to the Bureau of Mines. The conversion charge for red lead was less than 0.5 cent per pound higher than that for litharge. The reason for the narrow spread between litharge and red lead conversion charges was the significant increase in demand for the latter in bulk form by traction and industrial battery manufacturers. Automotive battery manufacturers were also reportedly using more red lead to aid in formation of the batteries, as the percentage of higher grade red lead uses for ceramics, etc., declined.

## FOREIGN TRADE

Exports of lead in concentrates of just under 10,000 tons were at the lowest level since lead concentrates were classified separately from mixed ores in 1978. This was attributed to the high level of world production in 1985, much of which represented coproduct or byproduct production from zinc and silver mines, and was available at competitively low prices. Over 75% of the exports of concentrates in 1985 went to Canada, which in turn supplied nearly 70% of the refined pig lead imported for domestic consumption. Exports of pig metal and wrought lead products were almost four times those of 1984, and scrap exports also increased significantly. Taiwan and Brazil were the major markets for U.S. scrap, receiving over 50% of the total, the lead content of which was estimated to be 60%. The Netherlands and the United Kingdom received 70% of the refined pig lead exported, most of which was thought to be destined for LME warehouses.

The United States had net imports for consumption of lead in all forms, including scrap and drosses or other residues, of 60,600 tons, compared with 142,600 tons in 1984 and 125,800 tons in 1983. No concentrates for consumption were received from Peru, a traditional supplier of about two-thirds of that category over recent past years. Honduras, the other significant traditional source, supplied about 60% of that category in 1985. Canada and Mexico supplied almost 80% of the metal in all forms, including scrap, but imports from Australia and Peru, the other traditional significant metal sources, declined dramatically.

Table 2.—U.S. import duties for lead materials, January 1, 1985

(Lead content)

| Item | TSUS No. | Most favored nation (MFN) | Least developed developing countries | Non-MFN |
|---|---|---|---|---|
| Ore | 602.10 | 0.75 cent per pound | Free[1] or current MFN rate. | 1.5 cents per pound. |
| Lead bullion | 624.02 | 3.5% ad valorem | do | 10.5% ad valorem. |
| Other unwrought | 624.03 | 3.5% ad valorem[2] | Current MFN rate only | 10.0% ad valorem. |
| Waste and scrap | 624.04 | 2.7% ad valorem | Free[1] or 2.3% ad valorem. | 11.5% ad valorem. |

[1] Free if eligible under General System of Preferences.

[2] Established at 3.0% ad valorem (retroactive to July 1, 1983) but not to be less than 1.0625 cents per pound, on Oct. 30, 1984, by the Omnibus Trade Act.

Imports of chrome yellow used for highway markings increased for the fourth consecutive year, but imports of litharge declined significantly as total imports of lead chemicals and compounds declined 15%. Mexico accounted for most of the U.S. imports of litharge and red lead, while Canada supplied over 40% of all other categories, including almost 60% of the chrome yellow. The Federal Republic of Germany and the United Kingdom supplied 30% of the latter category. The Federal Republic of Germany accounted for most of the lead acetate imported; Belgium, China, and the Republic of South Africa equally for most of the lead nitrate; Peru and the Netherlands equally for most of the lead arsenate; and Canada and the Netherlands for all of the other lead salts. Canada and Mexico supplied over 80% of the total U.S. imports of lead chemicals and compounds, including oxides.

## WORLD REVIEW

According to the ILZSG statistics, consumption of refined soft lead and antimonial lead in the market economy countries was 3.97 million tons, compared with 4.0 million in 1984 and about 3.8 million in both 1983 and 1982.[8] Estimated world consumption of lead in all forms during 1985 decreased 20,000 tons to 5.46 million from 5.48 million tons in 1984, compared with 5.25 and 5.21 million tons in 1983 and 1982, respectively. However, world primary refinery production increased by 50,000 tons in 1985 over that of 1984. The increase was primarily a result of considerable increases in Australian and U.S. mine production after recovery from lengthy strikes in 1984, which had caused considerable drawdown of world metal stocks. Secondary lead production was over 40% of the world's total refinery output for the second consecutive year, despite a significant dropoff in the United States.

ILZSG forecast that lead consumption during 1986 would be only about 15,000 tons greater than that of 1985 for the market economy countries, but that refined metal production would be about 60,000 tons greater with virtually no change in net exports to the centrally planned economy countries (CPEC) of about 100,000 tons. Mine production was expected to increase in 1986 by over 100,000 tons, with net exports of concentrates to the CPEC staying at about 60,000 tons of contained lead, according to ILZSG.

Despite some announced mine closings, there were several mine expansions, and six new mines were brought on-stream. The net result was an increase of 80,000 tons in world capacity to about 4.2 million tons per year. Primary refinery capacity remained at 4.53 million tons per year, but smelter capacity decreased by 80,000 tons per year to 4.36 million tons per year from yearend 1984.

**Australia.**—Record high mine production of lead was reported in 1985, which reflected the return to normal after lengthy strikes at three mines during 1984 at Broken Hill, New South Wales, and two mines in Tasmania. Also, increases were reported at EZ Industries Ltd.'s Elura Mine in New South Wales; at Mount Isa Mine in Queensland, the world's largest zinc-lead mine; and at the Woodlawn open pit at Tarago, New South Wales. Woodlawn became a 100% owned subsidiary of Australia Mining & Smelting Ltd. (AM&S) early in the year when it acquired St. Joe International Explorations Ltd.'s one-third vested interest. The open pit reportedly would be depleted in early 1987, but in early 1985 a ramp decline was started in order to further evaluate known lower-level mineralization for a potential continuance of the operation underground. The Woodcutters open pit near Darwin in the Northern Territory came on-stream in late 1985 after completion of the mill and prestripping operations in July. The mine was controlled by a consortium led by Nicron Resources Ltd. Further expansions at several mines were announced for 1986 following development work accomplished in 1985. These included EZ's Elura Mine; AM&S' CSA Mine at Cobar, New South Wales; North Broken Hill Holdings Ltd.'s (NBH) North Mine at Broken Hill, New South Wales; and Aberfoyle Ltd.'s Que River Mine on the west coast of Tasmania. Aberfoyle's production was expected to increase by about one-third at the beginning of 1986 and hold through 1991, and NBH's by about 20% by the end of 1986. Australia's mine capacity at yearend 1985 was estimated to be about 530,000 tons per year of lead in concentrates.

Extensive exploration by Aberfoyle continued at the Hellyer Prospect, 3 kilometers north of the Que River Mine, and a further 4 million tons of ore was inferred. A 1.2-

kilometer adit was driven from a nearby valley to allow underground exploration and bulk sampling in 1986. At Mount Isa Mines Ltd.'s (MIM) silver-lead-zinc Hilton Prospect, 20 kilometers north of Mount Isa, development work continued toward a mid-1986 trial mining operation, and possible phasing in with Mount Isa Mine's production in the late 1980's. Continuing exploratory drilling at Hilton North reportedly confirmed potentially economic silver-lead-zinc mineralization of a similar magnitude to that of Hilton. Mining of the lead carbonate cap of the Hilton ore body began in 1985 for use as a flux in MIM's smelter at Mount Isa. Pancontinental Mining Ltd. acquired MIM's interest in the Lady Loretta deposit in North Queensland in August and later acquired the remaining half of the joint venture from Elf Aquitaine Triako Mines NL. Late in the year, Pancontinental sold a 49% interest to Outokumpu Oy of Finland. Reserves were estimated at 9 million tons grading 14.8% zinc, 6.5% lead, and 95 grams per ton of silver. Exploration continued at the Blendevale Prospect in the northwestern part of Western Australia by the Pillara Joint Venture. Pillara was equally composed of BHP Minerals Ltd., the operator, and the Oscar Range Joint Venture, which was 77% vested by the Shell Co. of Australia and 23% by Trend Exploration Ltd.

Exports of lead concentrate increased during 1985 in line with the increased mine production. Smelter bullion exports decreased 18%, however, in order to rebuild stocks, which were drawn down in 1984 during the strikes, because production was about the same as in 1984. Refined lead exports increased slightly, but refinery production decreased about 2,000 tons, as did domestic consumption.

**Canada.**—Mine production and total refinery production, including secondary, decreased slightly compared with that of 1984, in response to reduced domestic and world demand. Those conditions, in concert with higher stripping ratios and increased dewatering and exploration costs, negatively affected Pine Point Mines Ltd.'s operation at Yellowknife in the Northwest Territory. Therefore, Pine Point announced in late December a revised mining plan to boost production rates in order to maximize cash flow during 1986 and 1987 by recovering only the most economic ore, and thereby decrease reserves by 5 million tons, allowing for a significant writedown of remaining assets and preproduction expenditures. Truck and shovel mining and underground operations were to continue into 1987, but dragline operations were suspended in 1985. Exploration was to continue on the eastern part of the property, where about 500,000 tons of new reserves reportedly were identified during the year. Pine Point is 51% owned by Cominco Ltd., and its life was not expected to extend beyond the opening of Cominco's Red Dog Mine in Alaska in 1989, according to some analysts. At 60,000 tons of lead in concentrates per year capacity, the Pine Point Mine is Canada's third largest lead producer.

Dome Petroleum Ltd. agreed to sell its subsidiary, Cyprus Anvil Mining Corp., and Faro Mine, situated 235 miles northeast of Whitehorse in the Yukon Territory, to Curragh Resources Corp. The Faro Mine was closed in June 1982, but a complex financial plan involving loan credit lines guaranteed by the Yukon and Federal Governments, and incentive contributions under terms of the Yukon Mineral Recovery Program, should allow the territory's largest mine to reopen in 1986. In addition, the Yukon Government was to buy 122 properties owned by the mine for $1.05 million cash, provide a second mortgage on 152 other properties worth $2.4 million, and pick up the cost of reopening and maintaining the Klondike Highway from Whitehorse to Skagway, Alaska's port. There was also to be a 2-year moratorium on interest payments on the loans, and the Yukon Government reached an agreement in principle with Alaska officials to pay one-half the capital and yearly maintenance costs of that portion of the highway in the United States. Full production of 4 million tons per year would not be reached until 1987, and the open pit reportedly would have a life of 7 years, but several nearby deposits showing potential were under review at yearend. At capacity, about 85,000 tons per year, the operation would surpass Pine Point as Canada's third largest lead producer. Boliden AB of Sweden contracted to be the general sales agent for Faro's production and also acquired a 10% interest in the mine. At yearend, Boliden reportedly located buyers for the 40,000 tons of lead concentrates and 90,000 tons of zinc concentrates, which was the anticipated limited production in 1986.

In November, the Canadian Federal Government proposed a $48 million financial package to Cominco for replacing its smelter at Trail, British Columbia, with two modified Soviet Kivcet-type autogenous flash furnaces, incorporating significant operating cost savings and improved environmental safeguards. Under terms of the agreement the Government, through the Federal Business Development Bank, would purchase a special new preferred share issue, which would be redeemable after 10 years and fully retired within 20 years. The money would be used to begin the $98 million phase 1, consisting of completing one furnace and one oxygen plant and beginning a concentrate dryer by 1988. Completion of the whole project, estimated to cost $189 million, would increase smelting and refining capacity 40,000 tons per year to 176,000 tons per year, including a 6-million-troy-ounce-per-year increase in refined silver capacity to 17 million troy ounces per year. At yearend, Cominco was trying to conclude an agreement on a water rate reduction with the Provincial government.

**China.**—A contract to construct a QSL process 50,000-ton-per-year lead smelter at Beijing was negotiated with Lurgi Gesellschaften, the construction subsidiary of the Federal Republic of Germany's Metallgesellschaft AG. It would be the first commercial plant in the world to use the QSL technology, which has been under demonstration on a pilot scale by Metallgesellschaft at Duisberg in the Federal Republic of Germany since 1982.

**India.**—The Government gave approval for Hindustan Zinc Ltd. (HZL) to construct a 35,000-ton-per-year ISF process lead smelter to service the developing Rampura Agucha zinc-lead deposit in Rajasthan. Smelter startup was not expected before 1990, with a first-year production of 21,000 tons. The open pit was expected to start up during 1989 at a capacity of 8,000 tons per year of lead and double HZL's existing mine capacity. Reserves were estimated to be 60 million tons of ore grading 1.9% lead and 13.5% zinc. A significant lead deposit was reportedly discovered in the Jharsi District about 9 kilometers from another known substantial deposit in the Bhupura area.

**Iran.**—Contract terms reportedly were finalized with Mannesmann Demag Hüttentechnik GmbH of the Federal Republic of Germany for construction of the National Iranian Lead and Zinc Co.'s proposed 40,000-ton-per-year primary lead smelter at Zanjan. In addition, the complex reportedly will have a capacity of 40,000 tons per year for zinc and was scheduled for completion by yearend 1988.

**Ireland.**—Bula Ltd., which owned the north end of the Navan lead-zinc deposit in County Meath since 1970, was negotiating at yearend 1985 to sell out to Tara Exploration and Development Co. Ltd. whose parent, Tara Mines Ltd., had been exploiting the south end of the ore body at the rate of 2 million tons per year since 1977. Tara was considering an underground linkup should the Government, which owned 49% of Bula, give its permission. Tara reportedly would expand its mill capacity by 450,000 tons per year if it acquired Bula.

**Italy.**—Società per Azioni Minero-Metallurgiche (SAMIM), the Government metals and minerals combine, increased its share to 64% of Sameton S.p.A., which had been a joint venture with Tonolli S.p.A., a family-owned company. SAMIM also planned to acquire the remaining shares and eventually all of Tonolli's other domestic operations. The equal partnership, originally established in October 1983, controlled most of the country's secondary copper and copper alloy production, plus 60% of its secondary lead capacity, concentrated in nine plants, and additionally produced about 200,000 tons per year of semifinished products including metallic byproducts and compounds. Under Sameton, Italy became a large net importer of copper and lead scrap, as it was created to concentrate on the value-added end of the production chain.

**Japan.**—Dowa Mining Co. Ltd. reportedly discovered a rich mixed sulfide ore deposit in the Nurukawa District with probable ore reserves of 1 million tons grading 10.3% lead, 21.1% zinc, 2.3% copper, 21 grams per ton of gold, and 318 grams per ton of silver.

**Korea, North.**—A significant expansion of the existing lead-zinc mine complex at Kemdok was reportedly under way. In recent years, the operation reportedly utilized only two-thirds of the 900,000-ton-per-year estimated capacity of the lead and zinc concentrator. At capacity by 1988, the increased production was to be shipped to a new metallurgical complex under construction at Tanchon, which was thought to be planned for the capability to produce 300,000 tons per year of lead and zinc metal.

**Korea, Republic of.**—Work continued at Korea Zinc Co.'s expansion of its electrolytic zinc plant with installation of a new electrolytic lead refinery, which was scheduled to open in 1986 at a rated capacity of 35,000 tons per year. A new zinc-lead deposit was reportedly under consideration for development by Young Poong Mining Co. Ltd. near the existing mines at Taebaek, approximately 280 kilometers southeast of Seoul.

**Morocco.**—Financing reportedly was secured for Société des Fonderies de Plomb de Zellidja's planned expansion of its primary lead smelter-refinery at Oued-El-Heimer. When completed in 1986, the capacity would be increased from 65,000 tons per year to 90,000 tons per year. A new movable Swedish concentrator, with a capacity of 160,000 tons per year, was obtained for use at a potential deposit near Erradidia that could yield 10,000 tons per year of lead in concentrates.

**Peru.**—Construction continued throughout the year on Peru's first privately owned primary lead smelter-refinery. By 1987, the plant at Sayán, near Lima, would have a capacity of 12,000 tons per year. Trial runs were reportedly begun by Fundición de Concentrados S.A. late in the year. Funding was obtained from the Inter-American Development Bank and the International Bank for Reconstruction and Development. Expansions of two Empresa Minera del Centro del Perú mines, plus one new mine brought on-stream in the private sector, plus another expansion, raised Peru's capacity by 16,000 tons per year to an estimated 221,000 tons per year of lead in concentrates at yearend.

**South Africa, Republic of.**—Shell South Africa (Pty.) Ltd. initiated development of its new open pit Pering Farm Mine at Reivilo in the Vryburg District of Northern Cape Province. Startup was expected in 1986 with a capacity of 6,000 tons per year of lead and 33,000 tons per year of zinc by 1987. Fry Metals Pty. Ltd. expanded its existing secondary lead smelter-refinery at Germiston, Transvaal, from a capacity of 15,000 tons per year to 25,000 tons per year and closed its 10,000-ton-per-year secondary plant at Berlin, East London, in Eastern Cape Province.

**Spain.**—A major expansion of Asturiana de Zinc S.A.'s Torrelavega Mine at Reocín, in Santander, reportedly was completed. The underground and open pit complex capacity was raised from 9,000 tons per year to 15,000 tons per year for lead, and from 15,000 tons per year to 70,000 tons per year for zinc.

**Tunisia.**—Société Tunisienne d'Expansion Minière S.A. continued expansion development work at the existing Fej Hassen Mine and Fej El Ahdoum Mine at Ghardimaou and Le Krib, respectively, which was expected to bring an additional 17,000 tons per year of capacity for lead and 10,000 tons per year of capacity for zinc on-stream by the end of 1986.

**Yugoslavia.**—Underground development at a new mine at Sastavci-Kizevak, with a projected capacity of 3,000 tons per year of lead, was expected to commence in 1986. Another mine in southern Serbia was expected to come on-stream in 1986 with a capacity of 2,000 tons per year of lead.

## TECHNOLOGY

A prototype lead-acid, battery-powered, jumbo ground transporter was placed in service for extensive testing during 1985 by one of the Nation's leading cargo-carrying airlines. The introduction of the 15.5-ton tractor with an integrated roller flatbed was the latest in a rapidly increasing series of heavy-duty, specialized, ground-support electric vehicles coming into widespread use in the airline and ocean shipping industries. For example, battery-powered ground support equipment (GSE) including pushout tractors, baggage tugs, and belt loaders penetrated the airline GSE market in the United States from near zero in 1980 to about 15% of all such vehicles in 1985, according to the Lead Industries Association Inc. The jumbo transporter was the latest of 13 such products introduced by the manufacturer during that time. The vehicle was powered by a 670-ampere-hour, 40-horsepower motor supplied by a 4-ton lead-acid battery system and reportedly could move at up to 12 miles per hour when loaded to its 15-ton maximum capacity.[4]

The Bureau of Mines announced a new process that extracts cobalt from Missouri lead-ore wastes. Although technically feasible, the process is not economic at this time. However, shortage conditions and increased prices for cobalt could create conditions to help make extraction faster than would be possible from new domestic mines, according to the Bureau. The process is based on conventional flotation technology using a special chemical collector in which rising bubbles in the cell concentrate the cobalt-bearing minerals at the top for skimming. It was estimated that as much as 65% of the cobalt, and from 60% to 90% of other trace metals in the tailings, such as silver, could be recovered. In recent times, Missouri lead ores have been at a competitive disadvantage on the world market because they have averaged only about one-half the coproduct and byproduct values of those found in other major lead-producing and exporting nations such as Australia, Canada, Mexico, and Peru. At yearend, research on the flotation process was continuing on a larger scale at an operating mill in cooperation with a commercial lead producer.[5]

A comprehensive coverage of lead-related investigations and an extensive review of current world literature on the extraction and uses of lead and its products were published in quarterly issues of Lead Abstracts, Lead Development Association, London, United Kingdom.

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[1] Physical scientist, Division of Nonferrous Metals.

[2] International Lead and Zinc Study Group (London). Lead and Zinc Statistics. ILZSG Monthly Bull., v. 26, No. 9, Sept. 1986, pp. 16-18.

[3] Work cited in footnote 2.

[4] Battery Man. V. 28, No. 4, Apr. 1986, pp. 22-24.

[5] Cornell, W. L., D. C. Holtgrefe, and F. H. Sharp. Recovery of Cobalt and Other Metal Values From Missouri Lead Ore Concentrator Tailings. Paper in Recycle and Secondary Recovery of Metals, ed. by P. R. Taylor, H. Y. Shon, and N. Jarrett (Proc. Int. Symp. on Recycle and Secondary Recovery of Met., Ft. Lauderdale, FL, Dec. 1-4, 1985). Metall. Soc. AIME, 1985, pp. 675-682.

**Table 3.—Mine production of recoverable lead in the United States, by State**

(Metric tons)

| State | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Alaska | W | W | W | -- | -- |
| Arizona | 993 | 359 | r234 | W | 581 |
| California | W | W | W | W | -- |
| Colorado | 11,431 | W | W | W | W |
| Idaho | 38,397 | W | 25,893 | W | 33,707 |
| Illinois | W | W | W | W | W |
| Missouri | 389,721 | 474,460 | 409,280 | 278,329 | 371,008 |
| Montana | 194 | 661 | 1,163 | W | 846 |
| Nevada | W | W | 14 | W | (1) |
| New Mexico | W | W | 258 | -- | W |
| New York | 968 | 1,065 | 1,299 | W | W |
| Oregon | W | -- | W | -- | -- |
| Tennessee | -- | -- | -- | W | W |
| Utah | 1,662 | W | -- | W | -- |
| Virginia | 1,607 | -- | -- | -- | -- |
| Washington | -- | W | -- | -- | -- |
| Total | 445,535 | 512,516 | r449,295 | r322,677 | 413,955 |

rRevised. W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Less than 1/2 unit.

**Table 4.—Mine production of recoverable lead in the United States, by month**

(Metric tons)

| Month | 1984r | 1985 |
|---|---|---|
| January | 42,001 | 31,778 |
| February | 42,838 | 33,252 |
| March | 46,451 | 37,582 |
| April | 20,973 | 39,256 |
| May | 24,135 | 37,069 |
| June | 12,282 | 32,485 |
| July | 24,234 | 34,451 |
| August | 23,588 | 34,808 |
| September | 18,664 | 30,929 |
| October | 22,464 | 36,882 |
| November | 19,575 | 32,476 |
| December | 25,472 | 32,987 |
| Total | 322,677 | 413,955 |

rRevised.

### Table 5.—Production of lead and zinc, in terms of recoverable metal, in the United States in 1985, by State

(Metric tons)

| State | Lead ore |  |  | Zinc ore |  |  | Lead-zinc ore |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | Gross weight (dry basis) | Lead | Zinc | Gross weight (dry basis) | Lead | Zinc | Gross weight (dry basis) | Lead | Zinc |
| Arizona | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Colorado | -- | -- | -- | -- | -- | -- | W | W | W |
| Idaho | -- | -- | -- | -- | -- | -- | W | W | W |
| Illinois | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Kentucky | -- | -- | -- | W | -- | W | -- | -- | -- |
| Missouri | 6,433,706 | 371,008 | 49,340 | -- | -- | -- | -- | -- | -- |
| Montana | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Nevada | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| New Jersey | -- | -- | -- | W | -- | W | -- | -- | -- |
| New Mexico | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| New York | -- | -- | -- | W | W | W | -- | -- | -- |
| Tennessee | -- | -- | -- | W | W | W | -- | -- | -- |
| Total | 6,433,706 | 371,008 | 49,340 | 4,261,858 | ([1]) | 161,580 | ([1]) | ([1]) | ([1]) |
| Percent of total lead or zinc | XX | 90 | 22 | XX | ([1]) | 71 | XX | ([1]) | ([1]) |

| State | Copper-lead, copper-zinc, copper-lead-zinc ores |  |  | All other sources[2] [3] |  |  | Total |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | Gross weight (dry basis) | Lead | Zinc | Gross weight (dry basis) | Lead | Zinc | Gross weight (dry basis) | Lead | Zinc |
| Arizona | -- | -- | -- | 51,010,198 | 581 | -- | 51,010,198 | 581 | -- |
| Colorado | -- | -- | -- | 37,508 | 643 | W | W | W | W |
| Idaho | -- | -- | -- | W | W | W | [3]901,337 | 33,707 | W |
| Illinois | -- | -- | -- | -- | W | W | ([3]) | W | W |
| Kentucky | -- | -- | -- | -- | -- | -- | W | -- | W |
| Missouri | -- | -- | -- | -- | -- | -- | 6,433,706 | 371,008 | 49,340 |
| Montana | -- | -- | -- | 2,616,424 | 846 | -- | 2,616,424 | 846 | -- |
| Nevada | -- | -- | -- | 73 | ([4]) | -- | 73 | ([4]) | -- |
| New Jersey | -- | -- | -- | -- | -- | -- | W | -- | W |
| New Mexico | -- | -- | -- | W | W | -- | W | W | -- |
| New York | -- | -- | -- | -- | -- | -- | W | W | W |
| Tennessee | -- | -- | -- | W | -- | W | 5,373,817 | W | 104,471 |
| Total | -- | -- | -- | 56,485,942 | 42,947 | 15,675 | 67,131,506 | 413,955 | 226,545 |
| Percent of total lead or zinc | XX | -- | -- | XX | 10 | 7 | XX | 100 | 100 |

W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.

[1] Included with "All other sources" to avoid disclosing company proprietary data.

[2] Includes lead and zinc recovered from lead-zinc ore in Colorado and Idaho and lead from zinc ores in New York and Tennessee in order to avoid disclosing company proprietary data. Also includes lead and zinc recovered from copper, gold, gold-silver, molybdenum, and silver ores, from fluorspar, and from mill tailings.

[3] Excludes tonnages of fluorspar in Illinois from which lead and zinc were recovered as byproducts, and molybdenum ore in Idaho from which lead was recovered as a byproduct.

[4] Less than 1/2 unit.

## Table 6.—Twenty-five leading lead-producing mines in the United States in 1985, in order of output

| Rank | Mine | County and State | Operator | Source of lead |
|---|---|---|---|---|
| 1 | Buick | Iron, MO | AMAX Lead Co. of Missouri | Lead ore. |
| 2 | Magmont | do | Cominco American Incorporated | Do. |
| 3 | Viburnum No. 29 | Washington, MO | St. Joe Minerals Corp | Do. |
| 4 | Fletcher | Reynolds, MO | do | Do. |
| 5 | Casteel Mine (formerly Viburnum No. 35) | Iron, MO | do | Do. |
| 6 | Lucky Friday | Shoshone, ID | Hecla Mining Co | Silver ore. |
| 7 | Viburnum No. 28 | Iron, MO | St. Joe Minerals Corp | Lead ore. |
| 8 | Leadville unit | Lake, CO | ASARCO Incorporated | Lead-zinc ore. |
| 9 | West Fork | Reynolds, MO | do | Lead ore. |
| 10 | Troy unit | Lincoln, MT | do | Copper ore. |
| 11 | Balmat | St. Lawrence, NY | St. Joe Minerals Corp | Zinc ore. |
| 12 | Star Morning | Shoshone, ID | Star Morning Co | Silver ore. |
| 13 | Clayton | Custer, ID | Clayton Silver Mines | Do. |
| 14 | Morenci | Greenlee, AZ | Phelps Dodge Corp | Copper ore. |
| 15 | Sunnyside | San Juan, CO | Standard Metals Corp | Gold ore. |
| 16 | Tiger | Pinal, AZ | McFarland & Hullinger | Gold-silver tailings. |
| 17 | Black Pine | Granite, MT | Black Pine Mining Co | Silver ore. |
| 18 | Rosiclare | Hardin and Pope, IL | Ozark-Mahoning Co | Fluorspar. |
| 19 | Ray | Pinal, AZ | Kennecott | Copper ore. |
| 20 | Sunshine | Shoshone, ID | Sunshine Mining Co | Silver ore. |
| 21 | Eisenhower | Pima, AZ | ASARCO Incorporated | Copper ore. |
| 22 | Canyon Silver | Shoshone, ID | Canyon Silver Lease | Lead-zinc ore. |
| 23 | Camp Bird | Ouray, CO | Federal Resources Corp | Silver ore. |
| 24 | Galena | Shoshone, ID | ASARCO Incorporated | Do. |
| 25 | Bulldog Mountain | Mineral, CO | Homestake Mining Co | Do. |

## Table 7.—Refined lead produced at primary refineries in the United States, by source material

(Metric tons unless otherwise specified)

| Source material | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Refined lead: | | | | | |
| From primary sources: | | | | | |
| Domestic ores and base bullion | 440,238 | 459,865 | 459,328 | 330,168 | 416,091 |
| Foreign ores and base bullion | 55,085 | 52,295 | 55,227 | 65,409 | 71,353 |
| Total | 495,323 | 512,160 | 514,555 | 395,577 | 487,444 |
| Calculated value of primary refined lead[1] thousands | \$398,908 | \$288,377 | \$245,938 | \$222,821 | \$204,899 |

[1] Value based on average quoted price.

## Table 8.—Stocks and consumption of new and old lead scrap in the United States, by type of scrap

(Metric tons, gross weight)

| Type of scrap | Stocks, Jan. 1 | Receipts | Consumption | | | Stocks, Dec. 31 |
|---|---|---|---|---|---|---|
| | | | New scrap | Old scrap | Total | |
| 1984 | | | | | | |
| Smelters, refiners, others: | | | | | | |
| Soft lead[1] | 1,477 | 31,276 | -- | 31,305 | 31,305 | 1,448 |
| Hard lead | 2,004 | 19,124 | -- | 19,506 | 19,506 | 1,622 |
| Cable lead | 1,924 | 12,705 | -- | 13,379 | 13,379 | 1,250 |
| Battery-lead plates | 42,411 | $^{r}$673,457 | -- | $^{r}$686,132 | $^{r}$686,132 | 29,736 |
| Mixed common babbitt | 130 | 1,956 | -- | 1,801 | 1,801 | 285 |
| Solder and tinny lead | 997 | $^{r}$17,284 | -- | $^{r}$16,144 | $^{r}$16,144 | $^{r}$2,137 |
| Type metals | 591 | 4,181 | -- | 4,270 | 4,270 | 502 |
| Drosses and residues | 5,706 | $^{r}$66,191 | $^{r}$64,086 | -- | $^{r}$64,086 | $^{r}$7,811 |
| Total | 55,240 | $^{r}$826,174 | $^{r}$64,086 | $^{r}$772,537 | $^{r}$836,623 | $^{r}$44,791 |

See footnotes at end of table.

## Table 8.—Stocks and consumption of new and old lead scrap in the United States, by type of scrap —Continued

(Metric tons, gross weight)

| Type of scrap | Stocks, Jan. 1 | Receipts | Consumption | | | Stocks, Dec. 31 |
|---|---|---|---|---|---|---|
| | | | New scrap | Old scrap | Total | |
| 1985 | | | | | | |
| Smelters, refiners, others: | | | | | | |
| Soft lead[1] | 1,448 | 31,156 | -- | 31,128 | 31,128 | 1,476 |
| Hard lead | 1,622 | 14,352 | -- | 15,280 | 15,280 | 694 |
| Cable lead | 1,250 | 3,278 | -- | 3,908 | 3,908 | 620 |
| Battery-lead plates | 29,736 | 643,157 | -- | 646,113 | 646,113 | 26,780 |
| Mixed common babbitt | 285 | 1,623 | -- | 1,610 | 1,610 | 298 |
| Solder and tinny lead | 2,137 | 20,656 | -- | 19,937 | 19,937 | 2,856 |
| Type metals | 502 | 3,370 | -- | 3,362 | 3,362 | 510 |
| Drosses and residues | 7,811 | 58,460 | 57,245 | -- | 57,245 | 9,026 |
| Total | 44,791 | 776,052 | 57,245 | 721,338 | 778,583 | 42,260 |

[r] Revised.

[1] Includes remelt lead from cable sheathing plus other soft lead scrap processing.

## Table 9.—Secondary metal recovered[1] from lead and tin scrap in the United States

(Metric tons)

| | Lead | Tin | Antimony | Other | Total |
|---|---|---|---|---|---|
| 1984 | | | | | |
| Refined pig lead | [r]247,929 | -- | -- | -- | [r]247,929 |
| Remelt lead | 15,502 | -- | -- | -- | 15,502 |
| Total | [r]263,431 | -- | -- | -- | [r]263,431 |
| Refined pig tin | -- | 1,097 | -- | -- | 1,097 |
| Remelt tin | -- | 10 | -- | -- | 10 |
| Total | -- | 1,107 | -- | -- | 1,107 |
| Lead and tin alloys: | | | | | |
| Antimonial lead | [r]327,803 | 894 | [r]12,292 | 685 | [r]341,674 |
| Lead-base babbitt | 1,481 | 123 | 162 | -- | 1,766 |
| Solder | 18,102 | 3,653 | 178 | 5 | 21,938 |
| Type metals | 2,312 | 142 | 329 | 4 | 2,787 |
| Other alloys including cable lead | 5,068 | 51 | 29 | 2 | 5,150 |
| Total | [r]354,766 | 4,863 | [r]12,990 | 696 | [r]373,315 |
| Tin content of chemical products | -- | 301 | -- | -- | 301 |
| Grand total | [r]618,197 | 6,271 | [r]12,990 | 696 | [r]638,154 |
| 1985 | | | | | |
| Refined pig lead | 249,904 | -- | -- | -- | 249,904 |
| Remelt lead | 13,361 | -- | -- | -- | 13,361 |
| Total | 263,265 | -- | -- | -- | 263,265 |
| Refined pig tin | -- | 1,292 | -- | -- | 1,292 |
| Remelt tin | -- | 10 | -- | -- | 10 |
| Total | -- | 1,302 | -- | -- | 1,302 |
| Lead and tin alloys: | | | | | |
| Antimonial lead | 287,967 | 791 | 9,722 | 524 | 299,004 |
| Lead-base babbitt | 1,195 | 88 | 130 | 4 | 1,417 |
| Solder | 21,647 | 3,565 | 161 | 10 | 25,383 |
| Type metals | 1,912 | 122 | 281 | 3 | 2,318 |
| Other alloys including cable lead | 3,235 | 10 | 6 | 1 | 3,252 |
| Total | 315,956 | 4,576 | 10,300 | 542 | 331,374 |
| Tin content of chemical products | -- | 186 | -- | -- | 186 |
| Grand total | 579,221 | 6,064 | 10,300 | 542 | 596,127 |

[r] Revised.

[1] Most of the figures herein represent actual reported recovery of metal from scrap.

## Table 10.—Secondary lead recovered in the United States

(Metric tons unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| **As metal:** | | | | | |
| In soft lead | 282,154 | 240,476 | 189,602 | [r]263,431 | 263,265 |
| In antimonial lead | 304,376 | 284,367 | 271,638 | [r]327,803 | 287,967 |
| In other alloys | 54,575 | 46,433 | 42,261 | 42,140 | 42,954 |
| Total: | | | | | |
| Quantity | 641,105 | 571,276 | 503,501 | [r]633,374 | 594,186 |
| Value[1] thousands | $516,313 | $321,663 | $240,655 | [r]$266,284 | $249,808 |

[r] Revised.

[1] Value based on average quoted price of common lead.

## Table 11.—Lead recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Metric tons)

| | 1984 | 1985 |
|---|---|---|
| KIND OF SCRAP | | |
| New scrap: | | |
| Lead-base | 44,342 | 39,715 |
| Copper-base | 3,278 | 3,000 |
| Tin-base | 5 | 5 |
| Total | 47,625 | 42,720 |
| Old scrap: | | |
| Battery-lead plates | [r]486,555 | 463,418 |
| All other lead-base | [r]87,130 | 76,047 |
| Copper-base | 12,064 | 12,000 |
| Tin-base | -- | 1 |
| Total | [r]585,749 | 551,466 |
| Grand total | [r]633,374 | 594,186 |
| FORM OF RECOVERY | | |
| As soft lead | [r]263,431 | 263,265 |
| In antimonial lead | [r]327,803 | 287,967 |
| In other lead alloys | 26,793 | 27,949 |
| In copper-base alloys | 15,342 | 15,000 |
| In tin-base alloys | 5 | 5 |
| Total | [r]633,374 | 594,186 |

[r] Revised.

## Table 12.—U.S. consumption of lead, by product

(Metric tons)

| SIC code | Product | 1984 | 1985 |
|---|---|---|---|
| | Metal products: | | |
| 3482 | Ammunition: Shot and bullets | 47,828 | 50,233 |
| | Bearing metals: | | |
| 35 | Machinery except electrical | 894 | 332 |
| 36 | Electrical and electronic equipment | 254 | 249 |
| 371 | Motor vehicles and equipment | 2,898 | 3,875 |
| 37 | Other transportation equipment | 631 | 936 |
| | Total bearing metals | 4,677 | 5,392 |
| 3351 | Brass and bronze: Billets and ingots | 6,954 | 7,823 |
| 36 | Cable covering: Power and communication | 12,270 | 15,501 |
| 15 | Calking lead: Building construction | 3,966 | 2,288 |
| | Casting metals: | | |
| 36 | Electrical machinery and equipment | 1,649 | 1,842 |
| 371 | Motor vehicles and equipment | 762 | 1,020 |
| 37 | Other transportation and equipment | 7,913 | 11,145 |
| 3443 | Nuclear radiation shielding | 5,480 | 5,407 |
| | Total casting metals | 15,804 | 19,414 |
| | Pipes, traps, other extruded products: | | |
| 15 | Building construction | 11,371 | 11,457 |
| 3443 | Storage tanks, process vessels, etc | 2,287 | 398 |
| | Total pipes, traps, other extruded products | 13,658 | 11,855 |
| | Sheet lead: | | |
| 15 | Building construction | 13,377 | 11,396 |
| 3443 | Storage tanks, process vessels, etc | 160 | 1,602 |
| 3693 | Medical radiation shielding | 1,128 | 1,833 |
| | Total sheet lead | 14,665 | 14,831 |
| | Solder: | | |
| 15 | Building construction | 6,543 | 4,469 |
| 341 | Metal cans and shipping containers | 3,275 | 2,894 |
| 367 | Electronic components and accessories | 5,361 | 4,187 |
| 36 | Other electrical machinery and equipment | 2,226 | 2,597 |
| 371 | Motor vehicles and equipment | 7,036 | 7,227 |
| | Total solder | 24,441 | 21,374 |
| | Storage batteries: | | |
| 3691 | Storage battery grids, post, etc | 426,300 | 468,746 |
| 3691 | Storage battery oxides | 439,242 | 372,194 |
| | Total storage batteries | 865,542 | 840,940 |
| 371 | Terne metal: Motor vehicles and equipment | 6,074 | 5,088 |
| 27 | Type metal: Printing and allied industries | 2,162 | 1,623 |
| 34 | Other metal products[1] | 8,284 | 5,570 |
| | Total metal products | 1,026,325 | 1,001,932 |
| | Other oxides: | | |
| 285 | Paints | 17,360 | 14,056 |
| 32 | Glass and ceramic products | 46,102 | 44,146 |
| 28 | Other pigments and chemicals | 13,346 | 14,561 |
| | Total other oxides | 76,808 | 72,763 |
| 2911 | Gasoline additives | 78,933 | 45,694 |
| | Miscellaneous uses | 24,967 | 27,909 |
| | Grand total | 1,207,033 | 1,148,298 |

[1] Includes lead consumed in foil, collapsible tubes, annealing, galvanizing, plating, and fishing weights.

## Table 13.—U.S. consumption of lead, by month[1]

(Metric tons)

| Month | 1984 | 1985 |
|---|---|---|
| January | 124,906 | 95,761 |
| February | 99,484 | 102,639 |
| March | 103,905 | 101,880 |
| April | 93,737 | 91,322 |
| May | 90,636 | 93,091 |
| June | 101,693 | 83,348 |
| July | 84,107 | 72,971 |
| August | 103,202 | 111,165 |
| September | 102,068 | 108,911 |
| October | 111,290 | 107,582 |
| November | 96,948 | 96,299 |
| December | 95,057 | 83,329 |
| Total[2] | 1,207,033 | 1,148,298 |

[1] Monthly totals include monthly reported consumption plus the prorated monthly distribution for companies that report on an annual basis only.

[2] Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide.

## Table 14.—U.S. consumption of lead in 1985, by State[1]

(Metric tons)

| State | Refined soft lead | Lead in antimonial lead | Lead in alloys | Lead in copper-base scrap | Total |
|---|---|---|---|---|---|
| California | 49,705 | 35,827 | 6,519 | 447 | 92,498 |
| Colorado | 1,002 | 310 | 53 | -- | 1,365 |
| Connecticut | 3,612 | 4,509 | -- | 179 | 8,300 |
| District of Columbia | 5 | -- | -- | -- | 5 |
| Florida | 11,558 | 7,597 | 1,252 | -- | 20,407 |
| Georgia | 22,500 | 7,860 | 4,367 | -- | 34,727 |
| Illinois | 29,813 | 37,550 | 2,622 | 603 | 70,588 |
| Indiana | 192,795 | 30,383 | 10,932 | 620 | 234,730 |
| Kansas | 12,245 | 6,633 | 4,495 | -- | 23,373 |
| Kentucky | 9,949 | 10,568 | 2,379 | -- | 22,896 |
| Maryland | 85 | -- | -- | 2 | 87 |
| Massachusetts | 556 | 168 | 24 | 48 | 796 |
| Michigan | 13,993 | 12,321 | 127 | -- | 26,441 |
| Missouri | 10,596 | 18,432 | -- | -- | 29,028 |
| Nebraska | 3 | -- | 389 | 716 | 1,108 |
| New Jersey | 48,432 | 22 | 812 | 199 | 49,465 |
| New York | 12,979 | 5,673 | 6,780 | -- | 25,432 |
| Ohio | 19,256 | 13,958 | 3,917 | 219 | 37,350 |
| Pennsylvania | 93,393 | 41,458 | 30,321 | 1,237 | 166,409 |
| Rhode Island | 1,922 | 41 | 12 | -- | 1,975 |
| Tennessee | 1,371 | 8,142 | 1,628 | 88 | 11,229 |
| Virginia and West Virginia | 50 | 484 | 1,154 | -- | 1,688 |
| Washington | 13,257 | 634 | -- | -- | 13,891 |
| Wisconsin | 966 | 121 | -- | 48 | 1,135 |
| Alabama and Mississippi | 9,293 | 4,865 | 2,084 | 1,568 | 17,810 |
| Arkansas and Oklahoma | 1,806 | 465 | 15 | -- | 2,286 |
| Hawaii and Oregon | 3,532 | 9,260 | 623 | -- | 13,415 |
| Iowa and Minnesota | 11,278 | 18,996 | 4,292 | -- | 34,566 |
| Louisiana and Texas | 83,563 | 20,291 | 4,379 | -- | 108,233 |
| Montana and Idaho | 76 | -- | -- | -- | 76 |
| New Hampshire, Maine, Vermont, Delaware | 14,181 | 14,317 | -- | 30 | 28,528 |
| North Carolina and South Carolina | 38,060 | 25,393 | 4,603 | -- | 68,056 |
| Utah, Nevada, Arizona | 202 | 26 | 177 | -- | 405 |
| Total | 712,034 | 336,304 | 93,956 | 6,004 | 1,148,298 |

[1] Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide.

## Table 15.—U.S. consumption of lead in 1985, by class of product

(Metric tons)

| Product | Soft lead | Lead in antimonial lead | Lead in alloys | Lead in copper-base scrap | Total[1] |
|---|---|---|---|---|---|
| Metal products | 68,032 | 61,412 | 25,545 | 6,003 | 160,992 |
| Storage batteries | 502,701 | 273,767 | 64,472 | -- | 840,940 |
| Other oxides | 72,763 | -- | -- | -- | 72,763 |
| Gasoline additives | 45,694 | -- | -- | -- | 45,694 |
| Miscellaneous | 22,844 | 1,125 | 3,939 | 1 | 27,909 |
| Total[1] | 712,034 | 336,304 | 93,956 | 6,004 | 1,148,298 |

[1] Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide.

## Table 16.—Production and shipments of lead pigments[1] and oxides in the United States

| Product | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Production (metric tons) | Shipments | | Production (metric tons) | Shipments | |
| | | Metric tons | Value[2] | | Metric tons | Value[2] |
| White lead, dry | 1,205 | 1,225 | $1,534,515 | 477 | 483 | $793,506 |
| Red lead | 11,629 | 11,236 | 10,046,120 | W | W | W |
| Litharge | 60,139 | 56,898 | 48,468,634 | 85,372 | 83,933 | 52,244,577 |
| Leady oxide | 462,329 | -- | -- | 380,440 | -- | -- |

W Withheld to avoid disclosing company proprietary data.
[1] Excludes basic lead sulfate; withheld to avoid disclosing company proprietary data.
[2] At plant, exclusive of container.

## Table 17.—Lead content of lead pigments[1] and oxides produced by domestic manufacturers

(Metric tons)

| Product | Lead in pigments from pig lead | |
|---|---|---|
| | 1984 | 1985 |
| White lead | 964 | 382 |
| Red lead | 10,582 | W |
| Litharge | 55,929 | 79,396 |
| Leady oxide | 439,213 | 361,419 |
| Total | 506,688 | [2]441,197 |

W Withheld to avoid disclosing company proprietary data; not included in "Total."
[1] Excludes basic lead sulfate; withheld to avoid disclosing company proprietary data.
[2] Excludes red lead.

## Table 18.—Distribution of red lead shipments in the United States, by industry

(Metric tons)

| Industry | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Paints | 3,172 | 2,395 | 2,533 | 2,384 | W |
| Ceramics | 2,307 | (1) | (1) | (1) | W |
| Storage batteries | 7,573 | (1) | (1) | (1) | W |
| Other | 2,025 | 11,274 | 12,364 | 8,852 | W |
| Total | 15,077 | 13,669 | 14,897 | 11,236 | W |

W Withheld to avoid disclosing company proprietary data.
[1] Withheld to avoid disclosing company proprietary data; included with "Other."

## Table 19.—Distribution of litharge shipments in the United States, by industry

(Metric tons)

| Industry | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Ceramics | 34,732 | 30,980 | 36,782 | 37,960 | 65,413 |
| Chrome pigments | 4,247 | 6,591 | 5,973 | 4,367 | 3,794 |
| Oil refining | 227 | W | W | W | W |
| Paints | 3,765 | 3,052 | 3,256 | 3,635 | 3,397 |
| Rubber | 1,107 | 787 | 933 | 1,016 | 739 |
| Other | 3,063 | 10,267 | 9,596 | 9,920 | 10,590 |
| Total | 47,141 | 51,677 | 56,540 | 56,898 | 83,933 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

## Table 20.—U.S. imports for consumption of lead pigments and compounds, by kind

| Kind | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| White lead | 442 | $524 | 315 | $426 |
| Red lead | 923 | 553 | 710 | 340 |
| Litharge | 12,726 | 6,314 | 9,955 | 4,074 |
| Chrome yellow | 2,322 | 4,223 | 2,886 | 4,426 |
| Other lead pigments | 342 | 1,189 | 536 | 1,138 |
| Other lead compounds | 2,326 | 2,219 | 1,870 | 2,064 |
| Total | 19,081 | 15,022 | 16,272 | 12,468 |

Source: Bureau of the Census.

## Table 21.—Stocks of lead at primary smelters and refineries in the United States, December 31

(Metric tons)

| Stocks | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Refined pig lead | 78,836 | 73,455 | 58,267 | 47,696 | 83,857 |
| Lead in antimonial lead | 666 | W | W | W | W |
| Lead-base bullion | 4,872 | 4,252 | 5,557 | 5,837 | 2,945 |
| Lead in ore and matte | 55,833 | 47,830 | 42,837 | 81,546 | 41,148 |
| Total | 140,207 | 125,537 | 106,661 | 135,079 | 127,950 |

W Withheld to avoid disclosing company proprietary data.

## Table 22.—Stocks of lead at consumers and secondary smelters in the United States, December 31

(Metric tons, lead content)

| Year | Refined soft lead | Lead in antimonial lead | Lead in alloys | Lead in copper-base scrap | Total |
|---|---|---|---|---|---|
| 1981 | 69,636 | 46,194 | 6,523 | 863 | 123,216 |
| 1982 | 51,036 | 40,118 | 5,346 | 709 | 97,209 |
| 1983 | 57,881 | 37,159 | 5,085 | 646 | 100,771 |
| 1984 | [r]53,802 | 37,015 | 5,326 | 934 | [r]97,077 |
| 1985 | 50,475 | 36,374 | 5,770 | 511 | 93,130 |

[r] Revised.

### Table 23.—Average monthly and annual quoted prices of lead[1]

(Cents per pound)

| Month | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | U.S. producer | London Metal Exchange | U.S. producer | London Metal Exchange |
| January | 25.12 | 18.01 | 19.09 | 19.03 |
| February | 24.07 | 18.33 | 18.82 | 16.69 |
| March | 25.03 | 20.82 | 17.68 | 15.96 |
| April | 26.43 | 21.83 | 19.92 | 17.65 |
| May | 25.37 | 20.54 | 20.11 | 17.04 |
| June | 28.16 | 21.95 | 19.05 | 17.64 |
| July | 30.51 | 22.37 | 18.88 | 18.27 |
| August | 28.24 | 21.18 | 19.10 | 18.74 |
| September | 24.18 | 18.20 | 19.20 | 18.15 |
| October | 22.33 | 18.67 | 18.93 | 17.83 |
| November | 25.25 | 19.96 | 19.05 | 17.86 |
| December | 21.89 | 18.83 | 18.97 | 17.67 |
| Average | 25.55 | 20.12 | 19.07 | 17.84 |

[1] Metals Week. Quotations for the United States on a nationwide, delivered basis. LME cash average.

### Table 24.—U.S. exports of lead, by country

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Ore and concentrates (lead content): |  |  |  |  |
| Canada | 11,675 | $4,627 | 7,529 | $2,986 |
| Germany, Federal Republic of | -- | -- | 642 | 734 |
| Haiti | 54 | 40 | -- | -- |
| Japan | -- | -- | 1,438 | 365 |
| Mexico | 43 | 13 | 23 | 7 |
| Netherlands | -- | -- | 354 | 410 |
| United Kingdom | 66 | 56 | -- | -- |
| Other | 20 | 24 | 1 | 1 |
| Total | 11,858 | 4,760 | 9,987 | 4,503 |
| Drosses and residues including flue dust (lead content): |  |  |  |  |
| Belgium-Luxembourg | 2,458 | 622 | 1,894 | 557 |
| Brazil | 4,353 | 1,080 | 1,831 | 359 |
| Canada | 274 | 562 | 3,527 | 1,186 |
| Denmark | 473 | 496 | -- | -- |
| Finland | -- | -- | 91 | 50 |
| France | -- | -- | 35 | 25 |
| Germany, Federal Republic of | 273 | 162 | 161 | 195 |
| Japan | -- | -- | 60 | 224 |
| Netherlands | 3 | 5 | 102 | 63 |
| United Kingdom | 1,268 | 2,421 | 2,210 | 2,929 |
| Other | 16 | 4 | 67 | 144 |
| Total | 9,118 | 5,352 | 9,978 | 5,732 |
| Unwrought lead and lead alloys (lead content): |  |  |  |  |
| Australia | 4 | 4 | 1 | 1 |
| Belgium-Luxembourg | 113 | 1,832 | 206 | 1,177 |
| Brazil | (1) | 5 | 1,498 | 421 |
| Canada | 2,817 | 2,181 | 1,783 | 1,006 |
| Chile | 174 | 178 | 385 | 630 |
| China | 8 | 288 | 1 | 26 |
| Dominican Republic | 56 | 42 | 67 | 60 |
| Egypt | 105 | 302 | 346 | 274 |
| Finland | 39 | 36 | -- | -- |
| France | 3 | 11 | 3 | 9 |
| Germany, Federal Republic of | 104 | 80 | 14 | 52 |
| Ghana | 100 | 66 | 1 | 5 |
| Haiti | 36 | 27 | 128 | 119 |
| Honduras | 3 | 4 | -- | -- |
| Israel | -- | -- | 544 | 216 |
| Japan | 148 | 184 | 71 | 90 |
| Korea, Republic of | 95 | 169 | 761 | 1,052 |
| Mexico | 584 | 766 | 364 | 230 |
| Netherlands | 66 | 850 | 15,511 | 8,428 |
| Netherlands Antilles | -- | -- | 34 | 24 |
| Nigeria | -- | -- | 310 | 195 |
| Panama | -- | -- | 56 | 51 |

See footnote at end of table.

### Table 24.—U.S. exports of lead, by country —Continued

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| **Unwrought lead and lead alloys (lead content) — Continued** | | | | |
| Peru | 15 | $17 | 90 | $109 |
| Philippines | 121 | 128 | 27 | 20 |
| Saudi Arabia | 16 | 33 | 16 | 51 |
| Singapore | 58 | 65 | 7 | 8 |
| Taiwan | 90 | 75 | 687 | 316 |
| Thailand | 12 | 15 | -- | -- |
| United Kingdom | 108 | 115 | 2,298 | 1,381 |
| Venezuela | 7 | 39 | 27 | 32 |
| Other | 78 | 157 | 142 | 217 |
| Total | 4,960 | 7,669 | 25,378 | 16,200 |
| **Wrought lead and lead alloys (lead content):** | | | | |
| Australia | -- | 2 | 4 | 14 |
| Barbados | -- | -- | 39 | 43 |
| Belgium-Luxembourg | 91 | 138 | -- | 2 |
| Brazil | -- | -- | 22 | 30 |
| Canada | 495 | 516 | 367 | 656 |
| Denmark | 17 | 25 | -- | -- |
| Ecuador | 4 | 8 | 5 | 11 |
| France | 15 | 34 | 3 | 36 |
| Germany, Federal Republic of | 11 | 19 | 41 | 178 |
| Honduras | 11 | 23 | 5 | 12 |
| Hong Kong | 33 | 50 | 5 | 36 |
| India | -- | -- | 2 | 2 |
| Israel | -- | -- | 2 | 8 |
| Italy | -- | 1 | 1 | 1 |
| Japan | 16 | 193 | 26 | 41 |
| Korea, Republic of | 25 | 95 | 18 | 159 |
| Mexico | 1,273 | 5,190 | 670 | 2,861 |
| Netherlands | 4 | 6 | 1 | 7 |
| Panama | 14 | 33 | 1 | 7 |
| Philippines | 10 | 30 | -- | -- |
| Saudi Arabia | 30 | 84 | 6 | 36 |
| Singapore | 33 | 62 | 41 | 34 |
| Spain | ([1]) | 1 | -- | -- |
| Taiwan | 98 | 319 | 543 | 236 |
| United Kingdom | 185 | 393 | 63 | 98 |
| Venezuela | 86 | 121 | 60 | 69 |
| Other | 34 | 202 | 39 | 200 |
| Total | 2,485 | 7,545 | 1,964 | 4,777 |
| **Scrap (gross weight):** | | | | |
| Australia | -- | -- | 18 | 8 |
| Belgium-Luxembourg | 345 | 388 | 383 | 176 |
| Brazil | 5,861 | 1,192 | 14,475 | 2,920 |
| Canada | 6,117 | 2,190 | 3,634 | 917 |
| Colombia | 5,649 | 548 | 6,185 | 882 |
| Denmark | 430 | 516 | -- | -- |
| Ecuador | 59 | 58 | 2 | 7 |
| Germany, Federal Republic of | 904 | 480 | 1,525 | 266 |
| Hong Kong | 156 | 77 | 15 | 7 |
| India | 298 | 167 | 450 | 88 |
| Ireland | -- | -- | 273 | 77 |
| Italy | -- | -- | 3,528 | 495 |
| Japan | 336 | 166 | 1,540 | 1,002 |
| Korea, Republic of | 1,550 | 331 | 3,053 | 978 |
| Mexico | 2,873 | 823 | 1,832 | 346 |
| Netherlands | 262 | 293 | 182 | 143 |
| Philippines | 1,000 | 239 | -- | -- |
| Spain | 513 | 73 | 18 | 2 |
| Switzerland | -- | -- | 68 | 20 |
| Taiwan | 13,530 | 2,803 | 17,262 | 2,477 |
| Trinidad and Tobago | 3,541 | 520 | 68 | 20 |
| United Kingdom | 659 | 400 | 1,633 | 891 |
| Venezuela | 992 | 300 | 3,738 | 1,067 |
| Other | 22 | 11 | 67 | 174 |
| Total | 45,097 | 11,575 | 59,949 | 12,963 |
| Grand total | 73,518 | 36,901 | 107,256 | 44,175 |

[1] Less than 1/2 unit.

Source: Bureau of the Census.

## Table 25.—U.S. exports of lead

| Year | Blocks, pigs, anodes, etc. | | | | Wrought lead and lead alloys | | | | Scrap (gross weight) | | Drosses, etc. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unwrought | | Unwrought alloys | | Sheets, plates, rods, other forms | | Foil, powder, flakes | | | | | |
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1983 | 13,244 | $8,895 | 4,440 | $2,409 | 2,406 | $6,866 | 359 | $920 | 50,918 | $13,139 | 3,902 | $3,080 |
| 1984 | 3,732 | 4,849 | 1,228 | 2,820 | 2,156 | 7,058 | 329 | 487 | 45,097 | 11,575 | 9,118 | 5,352 |
| 1985 | 23,468 | 14,050 | 1,910 | 2,150 | 1,870 | 4,635 | 94 | 142 | 59,949 | 12,963 | 9,978 | 5,732 |

Source: Bureau of the Census.

## Table 26.—U.S. imports[1] of lead, by country

(Lead content)

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Ore and concentrates:[2] | | | | | | |
| Australia | 10,002 | $2,865 | 17,024 | $5,689 | 12,260 | $2,407 |
| Bolivia | -- | -- | 816 | 390 | -- | -- |
| Canada | 6,143 | 1,234 | 14,127 | 5,242 | 5,195 | 1,246 |
| Chile | -- | -- | 904 | 189 | 765 | 106 |
| Honduras | 8,663 | 3,945 | 5,370 | 2,889 | 1,568 | 757 |
| Italy | -- | -- | 5,103 | 1,664 | -- | -- |
| Mexico | 4 | 1 | 2,803 | 1,630 | 4,321 | 1,356 |
| Peru | 22,702 | 7,041 | 22,718 | 8,671 | 15,176 | 4,017 |
| South Africa, Republic of | -- | -- | -- | -- | 3,381 | 1,316 |
| Other | 2 | 1 | 5 | 2 | -- | -- |
| Total | 47,516 | 15,087 | 68,870 | 26,366 | [3]42,665 | 11,205 |
| Base bullion: | | | | | | |
| Canada | 28 | 12 | 19 | 10 | 713 | 375 |
| France | -- | -- | 18 | 8 | -- | -- |
| Mexico | 25 | 10 | 6 | 37 | 48 | 23 |
| Other | (4) | 1 | (4) | 2 | -- | -- |
| Total | 53 | 23 | 43 | 57 | [3]760 | 398 |
| Pigs and bars: | | | | | | |
| Australia | 10,883 | 3,825 | 10,884 | 5,187 | 3,627 | 1,758 |
| Belgium-Luxembourg | 322 | 2,273 | 231 | 282 | 15 | 13 |
| Canada | 72,655 | 31,578 | 94,893 | 50,103 | 90,056 | 33,783 |
| Denmark | -- | -- | 11 | 4 | -- | -- |
| France | -- | -- | -- | -- | 20 | 9 |
| Germany, Federal Republic of | 1,022 | 7,020 | 1,528 | 4,205 | 542 | 3,080 |
| Italy | 113 | 79 | 418 | 316 | -- | -- |
| Mexico | 34,861 | 14,071 | 39,502 | 19,158 | 33,771 | 13,271 |
| Netherlands | 11 | 84 | 116 | 92 | 10 | 23 |
| Peru | 10,096 | 3,526 | 9,205 | 4,349 | 5,150 | 1,770 |
| South Africa, Republic of | -- | -- | 496 | 275 | -- | -- |
| Spain | -- | -- | 3,184 | 1,635 | -- | -- |
| United Kingdom | 716 | 898 | 974 | 943 | 337 | 807 |
| Other | 53 | 92 | 123 | 58 | -- | -- |
| Total | 130,732 | 63,446 | 161,565 | 86,607 | [3]133,529 | 54,514 |
| Reclaimed scrap, including drosses:[5] | | | | | | |
| Australia | 2,272 | 347 | 1,302 | 359 | -- | -- |
| Bahamas | 90 | 6 | -- | -- | -- | -- |
| Canada | 2,718 | 861 | 2,311 | 1,099 | 1,118 | 454 |
| Mexico | 1,551 | 371 | 2,638 | 864 | 2,035 | 720 |
| United Kingdom | 93 | 20 | 48 | 23 | -- | -- |
| Other | 29 | 106 | 3 | 13 | 15 | 34 |
| Total | 6,753 | 1,711 | [3]6,303 | 2,358 | 3,168 | 1,208 |

See footnotes at end of table.

## Table 26.—U.S. imports[1] of lead, by country —Continued

(Lead content)

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| **Pigs and bars:** | | | | | | |
| London Metal Exchange (return of U.S. brands)[6] | 42,000 | $16,945 | -- | -- | -- | -- |
| Grand total | 227,054 | 97,212 | 236,781 | $115,388 | 180,122 | $67,325 |

[1] Data are "general imports"; that is, they include lead imported for immediate consumption plus material entering the country under bond.

[2] Also includes other lead-bearing materials containing greater than 5 troy ounces of gold per short ton, or greater than 100 troy ounces of total precious metals per short ton.

[3] Data do not add to total shown because of independent rounding.

[4] Less than 1/2 unit.

[5] Also includes other lead-bearing materials containing greater than 10% by weight of copper, lead, or zinc (any one).

[6] Bureau of Mines estimate.

Source: Bureau of the Census.

## Table 27.—U.S. imports for consumption of lead, by country

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| **Ore and concentrates (lead content):**[1] | | | | | | |
| Canada | 483 | $112 | 1,843 | $477 | -- | -- |
| Chile | -- | -- | -- | -- | 765 | $106 |
| Honduras | 1,522 | 674 | 4,121 | 2,201 | 1,568 | 757 |
| Italy | -- | -- | 1,569 | 467 | -- | -- |
| Mexico | 4 | 1 | 2,654 | 1,550 | 317 | 116 |
| Peru | 17,742 | 4,924 | 19,695 | 7,226 | -- | -- |
| Other | 2 | 1 | 5 | 2 | -- | -- |
| Total[2] | 19,753 | 5,712 | 29,888 | 11,923 | 2,649 | 979 |
| **Base bullion (lead content):** | | | | | | |
| Canada | 28 | 12 | 19 | 10 | 713 | 375 |
| France | -- | -- | 18 | 8 | -- | -- |
| Mexico | 25 | 10 | 6 | 37 | 48 | 23 |
| Other | (3) | 1 | (3) | 2 | -- | -- |
| Total[2] | 53 | 23 | 43 | 57 | 760 | 398 |
| **Pigs and bars (lead content):** | | | | | | |
| Australia | 14,508 | 4,604 | 9,978 | 4,364 | 91 | 443 |
| Belgium-Luxembourg | 322 | 2,273 | 231 | 282 | 15 | 14 |
| Canada | 72,655 | 31,578 | 94,815 | 50,062 | 90,056 | 33,783 |
| Denmark | -- | -- | 11 | 4 | -- | -- |
| France | -- | -- | -- | -- | 20 | 9 |
| Germany, Federal Republic of | 1,022 | 7,020 | 1,528 | 4,205 | 542 | 3,080 |
| India | -- | -- | 907 | 447 | 1,361 | 664 |
| Italy | 113 | 79 | 419 | 316 | -- | -- |
| Mexico | 34,861 | 14,071 | 39,502 | 19,158 | 33,771 | 13,271 |
| Netherlands | 11 | 84 | 116 | 92 | 10 | 23 |
| Peru | 10,096 | 3,526 | 9,205 | 4,349 | 5,150 | 1,770 |
| South Africa, Republic of | -- | -- | 496 | 275 | -- | -- |
| Spain | -- | -- | 3,184 | 1,635 | -- | -- |
| United Kingdom | 716 | 898 | 974 | 943 | 337 | 807 |
| Other | 53 | 92 | 121 | 58 | -- | -- |
| Total[2] | 134,357 | 64,225 | 161,489 | 86,189 | 131,353 | 53,864 |
| **Reclaimed scrap, etc. (lead content):**[4] | | | | | | |
| Australia | 6 | 6 | 27 | 30 | -- | -- |
| Bahamas | 90 | 6 | -- | -- | -- | -- |
| Canada | 2,443 | 831 | 2,311 | 1,099 | 1,118 | 454 |

See footnotes at end of table.

## Table 27.—U.S. imports for consumption of lead, by country —Continued

| Country | 1983 Quantity (metric tons) | 1983 Value (thousands) | 1984 Quantity (metric tons) | 1984 Value (thousands) | 1985 Quantity (metric tons) | 1985 Value (thousands) |
|---|---|---|---|---|---|---|
| Reclaimed scrap, etc. (lead content)[4] —Continued | | | | | | |
| Guatemala | 14 | $6 | -- | -- | -- | -- |
| Mexico | 1,551 | 371 | 2,638 | $864 | 2,035 | $720 |
| United Kingdom | 93 | 20 | 48 | 23 | -- | -- |
| Other | 15 | 100 | 3 | 13 | 15 | 38 |
| Total[2] | 4,212 | 1,340 | 5,026 | 2,029 | 3,168 | 1,212 |
| Sheets, pipe, shot, other forms: | | | | | | |
| Belgium-Luxembourg | 16 | 32 | 90 | 107 | 44 | 57 |
| Canada | 228 | 238 | 471 | 837 | 419 | 627 |
| Germany, Federal Republic of | 216 | 1,189 | 315 | 1,693 | 149 | 576 |
| Italy | -- | -- | (3) | 2 | 1 | 13 |
| Mexico | 10 | 64 | 669 | 853 | 164 | 147 |
| Peru | -- | -- | -- | -- | 121 | 61 |
| Spain | -- | -- | -- | -- | 36 | 11 |
| United Kingdom | 3 | 14 | 51 | 128 | 1,027 | 809 |
| Other | 23 | 95 | 72 | 424 | 20 | 216 |
| Total[2] | 496 | 1,632 | 1,667 | 4,044 | 1,981 | 2,517 |
| Pigs and bars (lead content): | | | | | | |
| London Metal Exchange (return of U.S. brands)[5] | 42,000 | 16,945 | -- | -- | -- | -- |
| Grand total[2] | 200,871 | 89,877 | 198,108 | 104,241 | 139,911 | 58,970 |

[1] Also includes other lead-bearing materials containing greater than 5 troy ounces of gold per short ton, or greater than 100 troy ounces of total precious metals per short ton.
[2] Data may not add to totals shown because of independent rounding.
[3] Less than 1/2 unit.
[4] Also includes other lead-bearing materials containing greater than 10% by weight of copper, lead, or zinc (any one).
[5] Bureau of Mines estimate.

Source: Bureau of the Census.

## Table 28.—U.S. imports for consumption of lead

(Thousand metric tons and thousand dollars)

| Year | Ore and concentrate (lead content) | | Base bullion (lead content) | | Pigs and bars (lead content) | | Sheets, plates, strip, other forms | |
|---|---|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| 1981 | 27 | 20,196 | (1) | 340 | 100 | 87,026 | (1) | 564 |
| 1982 | 19 | 8,784 | (1) | 28 | 95 | 58,633 | (1) | 646 |
| 1983 | 20 | 5,712 | (1) | 23 | [2]176 | [2]81,170 | 1 | 1,628 |
| 1984 | 30 | 11,923 | (1) | 57 | 161 | 86,189 | 2 | 3,720 |
| 1985 | 3 | 979 | 1 | 398 | 131 | 53,864 | 2 | 2,394 |

| Year | Waste and scrap (lead content) | | Dross, skimmings, residues, n.s.p.f. (lead content) | | Powder and flakes | | Total value |
|---|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value | |
| 1981 | 2 | 1,568 | 1 | 652 | (1) | 162 | 110,508 |
| 1982 | 4 | 1,473 | 1 | 282 | (1) | 48 | 69,894 |
| 1983 | 3 | 980 | 1 | 360 | (1) | 4 | 89,877 |
| 1984 | 4 | 1,665 | 1 | 363 | (1) | 324 | 104,241 |
| 1985 | 2 | 1,068 | 1 | 144 | (1) | 123 | 58,970 |

[1] Less than 1/2 unit.
[2] Includes Bureau of Mines estimate of 42,000 metric tons of U.S. brands returned from the London Metal Exchange with an estimated value of $16,945,000.

Source: Bureau of the Census.

## Table 29.—U.S. imports for consumption of miscellaneous products containing lead[1]

| Year | Gross weight (metric tons) | Lead content (metric tons) | Value (thousands) |
|---|---|---|---|
| 1982 | 1,423 | 639 | $10,596 |
| 1983 | 2,312 | 1,131 | 13,720 |
| 1984 | 2,671 | 1,363 | 17,299 |
| 1985 | 3,377 | 1,453 | 22,124 |

[1] Babbitt metal, solder, white metal, and other lead-containing combinations.

Source: Bureau of the Census.

## Table 30.—Lead: World mine production of lead in concentrates, by country[1]

(Thousand metric tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria[e] | [r]5.0 | [r]5.0 | [r]3.0 | [r]4.0 | 3.0 |
| Argentina | 32.7 | 30.1 | 31.7 | 28.5 | 29.0 |
| Australia | 388.1 | 455.3 | 480.6 | 440.7 | 491.0 |
| Austria | 4.3 | 4.1 | 4.3 | 4.2 | 6.1 |
| Bolivia | 16.8 | 12.4 | 11.8 | 7.4 | 7.5 |
| Brazil | 21.7 | 19.4 | 18.8 | 16.7 | 19.0 |
| Bulgaria[e] | 116.0 | 95.0 | 95.0 | 95.0 | 95.0 |
| Burma | 16.1 | 16.1 | 23.1 | 21.9 | 22.0 |
| Canada | 332.0 | 341.2 | 251.5 | 264.3 | 278.0 |
| Chile | .2 | [r]1.6 | 1.7 | 4.3 | [3]2.5 |
| China[e] | 160.0 | 160.0 | 160.0 | 160.0 | 160.0 |
| Colombia | [r].2 | [r].2 | .2 | .1 | .1 |
| Congo (Brazzaville) | 7.7 | 4.1 | [e]6.0 | [e]2.0 | 4.0 |
| Czechoslovakia | 3.4 | 3.1 | 3.2 | 3.1 | 3.2 |
| Ecuador | .2 | .2 | .2 | .2 | .2 |
| Finland | [r]1.6 | 1.9 | 2.1 | 2.5 | 2.4 |
| France | 17.2 | 5.9 | 1.5 | 2.3 | 1.6 |
| Germany, Federal Republic of | 21.6 | 23.5 | 23.5 | 21.0 | [3]20.5 |
| Greece[e] | [r]23.0 | 19.0 | 20.0 | [r]22.0 | 20.0 |
| Greenland | [r]26.9 | [r]26.5 | 22.0 | 17.7 | [3]17.8 |
| Honduras | 12.6 | 15.1 | 19.3 | 20.5 | 21.3 |
| Hungary[e] | .5 | .6 | .7 | .7 | .7 |
| India | 15.3 | [e]16.6 | [e]25.7 | 24.8 | [3]28.0 |
| Iran[e] | 20.0 | 25.0 | [r]20.0 | [r]20.0 | 20.4 |
| Ireland | [r]28.8 | [r]36.0 | 33.6 | 37.2 | 34.0 |
| Italy | [r]21.3 | 16.2 | 23.6 | 20.8 | [3]15.6 |
| Japan | 46.9 | 45.9 | 46.9 | 48.7 | [3]50.0 |
| Korea, North[e] | 110.0 | 95.0 | 75.0 | [r]110.0 | 110.0 |
| Korea, Republic of | 13.4 | 12.2 | 12.2 | 10.8 | 8.8 |
| Mexico | 148.9 | 170.2 | 184.3 | 202.6 | 200.0 |
| Morocco | [r]117.7 | 103.6 | 97.9 | 100.7 | 101.0 |
| Namibia | 46.9 | 32.9 | 38.5 | 33.3 | [3]34.6 |
| Nigeria[e] | .2 | .3 | .3 | .3 | .3 |
| Norway | 3.0 | [e]3.7 | 4.1 | 3.5 | 3.4 |
| Peru | 192.7 | 175.8 | 212.6 | 205.3 | [3]209.9 |
| Philippines | 1.1 | -- | -- | -- | -- |
| Poland | [r]44.2 | [r]45.3 | 47.0 | 52.8 | 53.0 |
| Romania[e] | 25.0 | 27.0 | 30.0 | 30.0 | 28.0 |
| South Africa, Republic of | 98.9 | 90.3 | 87.5 | 94.8 | [3]98.4 |
| Spain | 80.2 | 73.3 | 82.0 | 96.6 | [3]86.7 |
| Sweden | [r]85.0 | [r]80.0 | 78.2 | 80.5 | 73.5 |
| Thailand | 17.3 | 18.6 | 21.0 | 16.7 | 20.0 |
| Tunisia | 5.7 | 5.0 | 4.6 | 4.1 | [3]3.6 |
| Turkey | [r]8.4 | [r]10.7 | 9.1 | 14.6 | 14.4 |
| U.S.S.R.[e] | 425.0 | 430.0 | 435.0 | 440.0 | 440.0 |
| United Kingdom | 7.0 | 4.0 | 3.8 | 2.4 | 3.0 |
| United States | 459.0 | 530.3 | 465.6 | 334.5 | [3]424.4 |
| Yugoslavia | 118.6 | 113.1 | 114.0 | 113.6 | 110.0 |
| Zambia | 17.2 | 21.2 | 25.9 | 18.1 | 15.8 |
| Total | [r]3,365.5 | [r]3,422.5 | 3,358.6 | 3,255.8 | 3,391.7 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through June 24, 1986.

[2] In addition to the countries listed, Uganda may produce lead, but available information is inadequate to make reliable estimates of output levels.

[3] Reported figure.

## Table 31.—Lead: World smelter production, by country[1]

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina: | | | | | |
| Primary (refined) | 19.0 | 17.0 | 16.0 | [e]19.0 | 18.0 |
| Secondary (refined) | 15.6 | 14.6 | 15.0 | [e]17.0 | 16.0 |
| Total | 34.6 | 31.6 | 31.0 | 36.0 | 34.0 |
| Australia: | | | | | |
| Primary: | | | | | |
| Bullion for export | 162.6 | 181.6 | 182.6 | 179.5 | [2]183.3 |
| Refined | 207.7 | 218.8 | 196.3 | 198.8 | [2]196.2 |
| Secondary (refined)[e] | 31.5 | 28.3 | [r]27.0 | 21.5 | 15.9 |
| Total | 401.8 | 428.7 | 405.9 | 399.8 | 395.4 |
| Austria: | | | | | |
| Primary | 3.3 | 3.4 | 4.2 | 1.7 | 1.7 |
| Secondary | 12.8 | 14.5 | 12.9 | 16.5 | 16.8 |
| Total | 16.1 | 17.9 | 17.1 | 18.2 | 18.5 |
| Belgium: | | | | | |
| Primary[e] [3] | 60.2 | 52.9 | [r]54.4 | [r]71.5 | 59.6 |
| Secondary[4] | 28.0 | 28.0 | 30.0 | 30.0 | 28.0 |
| Total | 88.2 | 80.9 | 84.4 | 101.5 | 87.6 |
| Brazil: | | | | | |
| Primary (refined) | 34.7 | 21.9 | 20.6 | 26.0 | 27.0 |
| Secondary (refined) | [r]29.0 | [r]26.3 | 28.9 | 37.7 | 40.0 |
| Total | [r]63.7 | [r]48.2 | 49.5 | 63.7 | 67.0 |
| Bulgaria:[e] | | | | | |
| Primary | 115.0 | 114.0 | 112.0 | 112.0 | 112.0 |
| Secondary[4] | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Total | 119.0 | 118.0 | 116.0 | 116.0 | 116.0 |
| Burma: Primary (refined) | 4.1 | 7.8 | 7.6 | 7.0 | [2]9.6 |
| Canada: | | | | | |
| Primary (refined) | 168.5 | 174.3 | 178.1 | 173.0 | 172.7 |
| Secondary (refined) | 69.7 | 64.6 | 63.9 | 79.0 | 66.8 |
| Total | 238.2 | 238.9 | 242.0 | 252.0 | 239.5 |
| China:[e] | | | | | |
| Primary (refined) | 150.0 | 155.0 | 165.0 | 165.0 | 165.0 |
| Secondary (refined) | 25.0 | 20.0 | 30.0 | 30.0 | 30.0 |
| Total | 175.0 | 175.0 | 195.0 | 195.0 | 195.0 |
| Colombia: Secondary (refined)[e] | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Cyprus: Secondary (refined)[e] | 2.5 | 2.5 | 2.5 | 2.5 | 2.0 |
| Czechoslovakia: Secondary (refined) | 21.0 | 21.0 | 21.0 | 21.1 | 21.5 |
| Denmark: Secondary (refined) | 24.0 | 15.9 | 10.0 | 13.0 | 4.5 |
| Finland: Secondary (refined) | 4.5 | 4.4 | 6.0 | 4.5 | 4.4 |
| France: | | | | | |
| Primary (refined) | 128.6 | 122.7 | 114.9 | 117.9 | 132.3 |
| Secondary | [r]35.3 | [r]22.4 | 37.4 | 24.9 | 36.4 |
| Total | [r]163.9 | [r]145.1 | 152.3 | 142.8 | 168.7 |
| German Democratic Republic: Secondary (refined)[e] [4] | [r]43.0 | [r]38.0 | [r]36.0 | [r]35.0 | 36.0 |
| Germany, Federal Republic of: | | | | | |
| Primary | 107.5 | 110.7 | 116.2 | 102.3 | [2]109.7 |
| Secondary | 254.8 | 239.7 | 236.3 | 254.9 | 246.8 |
| Total | 362.3 | 350.4 | 352.5 | 357.2 | [2]356.5 |
| Greece: | | | | | |
| Primary (refined) | 21.0 | 3.2 | -- | (5) | 15.0 |
| Secondary (refined) | 4.0 | -- | -- | -- | -- |
| Total | 25.0 | 3.2 | -- | (5) | 15.0 |
| Guatemala: Secondary (refined) | .1 | .1 | .1 | .1 | .1 |
| Hungary: Secondary (refined)[e] | .1 | .1 | .1 | .1 | .1 |

See footnotes at end of table.

### Table 31.—Lead: World smelter production, by country[1] —Continued

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| **India:** | | | | | |
| Primary (refined) | 14.3 | [e]14.4 | 15.0 | 15.2 | [2]15.6 |
| Secondary (refined) | 11.1 | [e]8.8 | 6.6 | [r] [e]10.0 | 10.0 |
| Total | 25.4 | [e]23.2 | 21.6 | [r] [e]25.2 | 25.6 |
| **Ireland:** Secondary (refined)[e] | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| **Italy:** | | | | | |
| Primary (refined) | 35.6 | 36.4 | 37.0 | 37.6 | [2]29.5 |
| Secondary (refined) | 97.4 | 97.3 | 89.4 | 102.9 | 95.0 |
| Total | 133.0 | 133.7 | 126.4 | 140.5 | 124.5 |
| **Jamaica:** Secondary (refined)[e] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| **Japan:** | | | | | |
| Primary | 190.7 | 192.8 | 198.9 | 207.9 | [2]218.3 |
| Secondary (refined) | 141.6 | 119.1 | 118.3 | 129.2 | [2]133.3 |
| Total | 332.3 | 311.9 | 317.2 | 337.1 | [2]351.6 |
| **Korea, North:** Primary (refined)[e] | 65.0 | 60.0 | 60.0 | [r]95.0 | 95.0 |
| **Korea, Republic of:**[e] | | | | | |
| Primary (refined) | 7.2 | 9.5 | 10.5 | [r]12.0 | 14.5 |
| Secondary (refined) | 7.5 | 6.6 | 7.3 | [r]8.3 | 7.9 |
| Total | 14.7 | 16.1 | 17.8 | 20.3 | 22.4 |
| **Malaysia:** Secondary (refined) | [e]3.5 | 3.0 | [e]4.0 | [r] [e]9.0 | 8.8 |
| **Mexico:** | | | | | |
| Primary | 156.7 | 145.4 | 166.8 | 174.8 | 175.0 |
| Secondary (refined)[e] | 38.0 | 34.0 | [r]29.0 | [r]25.0 | 25.0 |
| Total | 194.7 | 179.4 | 195.8 | 199.8 | 200.0 |
| **Morocco:** | | | | | |
| Primary (refined) | 50.1 | 56.5 | 55.2 | 46.1 | 46.0 |
| Secondary (refined)[e] | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 |
| Total[e] | 52.2 | 58.5 | [r]57.2 | [r]48.1 | 48.0 |
| **Namibia:** Primary (refined) | 41.7 | 40.6 | 35.4 | 28.9 | [2]38.5 |
| **Netherlands:** | | | | | |
| Primary[e] | 2.5 | 2.5 | 2.5 | 2.5 | 3.0 |
| Secondary (refined) | [r]33.9 | [r]27.7 | 23.6 | 33.6 | 37.6 |
| Total | [r]36.4 | [r]30.2 | 26.1 | 36.1 | 40.6 |
| **New Zealand:** Secondary (refined)[e] | 7.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| **Nigeria:** Secondary (refined)[e] | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 |
| **Pakistan:** Secondary (refined)[e] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| **Peru:** | | | | | |
| Primary (refined) | 79.2 | 77.0 | 67.7 | 70.3 | [2]81.9 |
| Secondary (refined)[e] | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Total | 84.2 | 82.0 | 72.7 | 75.3 | 86.9 |
| **Philippines:** Secondary (refined) | 4.0 | 6.0 | 6.0 | 4.0 | 4.0 |
| **Poland:**[e] | | | | | |
| Primary (refined) | 47.0 | 55.0 | 56.5 | 58.4 | 61.1 |
| Secondary (refined)[4] | 22.0 | 23.8 | 24.5 | 25.0 | 26.2 |
| Total | 69.0 | 78.8 | 81.0 | 83.4 | [2]87.3 |
| **Portugal:** Secondary (refined) | 5.3 | 4.0 | 6.0 | 6.0 | 6.0 |
| **Romania:** | | | | | |
| Primary (refined)[e] | [r] [2]40.7 | 40.5 | 40.0 | 39.0 | 39.0 |
| Secondary (refined)[e] | 5.0 | 5.2 | 9.3 | 10.0 | 10.0 |
| Total | [r]45.7 | 45.7 | 49.3 | [e]49.0 | 49.0 |
| **South Africa, Republic of:** Secondary (refined) | 26.9 | 30.4 | 23.6 | 21.9 | 20.0 |
| **Spain:** | | | | | |
| Primary (refined)[3] | [r]83.0 | 99.5 | 107.8 | 110.1 | 110.0 |
| Secondary (refined) | 34.1 | 32.1 | 36.0 | 49.9 | 45.0 |
| Total | [r]117.1 | 131.6 | 143.8 | 160.0 | 155.0 |

See footnotes at end of table.

## Table 31.—Lead: World smelter production, by country[1] —Continued

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984^p | 1985^e |
|---|---|---|---|---|---|
| **Sweden:** | | | | | |
| **Primary** | ^r21.8 | ^r63.7 | 62.8 | 65.7 | 66.0 |
| **Secondary** | ^r21.5 | ^r20.4 | 17.8 | 23.4 | 20.0 |
| **Total** | ^r43.3 | ^r84.1 | 80.6 | 89.1 | 86.0 |
| **Switzerland**: Secondary (refined) | 4.0 | 3.0 | 2.0 | 2.0 | 2.0 |
| **Taiwan**: Secondary (refined)^e | 30.0 | 35.0 | 38.0 | ^r44.3 | 44.4 |
| **Thailand**: Secondary (refined) | .5 | .9 | 3.2 | 6.2 | 6.0 |
| **Trinidad and Tobago**: Secondary (refined)^e | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| **Tunisia:** | | | | | |
| **Primary (refined)** | 17.5 | 15.3 | 10.4 | 8.4 | 10.0 |
| **Secondary (refined)^e** | .5 | .5 | .5 | .5 | .5 |
| **Total^e** | 18.0 | 15.8 | 10.9 | ^r8.9 | 10.5 |
| **Turkey: Primary (refined)** | ^r2.5 | ^r3.1 | 4.0 | 4.0 | 3.6 |
| **U.S.S.R.:^e** | | | | | |
| **Primary (refined)** | 480.0 | 485.0 | 490.0 | 495.0 | 495.0 |
| **Secondary (refined)** | 235.0 | 245.0 | 255.0 | 260.0 | 265.0 |
| **Total** | 715.0 | 730.0 | 745.0 | 755.0 | 760.0 |
| **United Kingdom:** | | | | | |
| **Primary[6]** | 26.5 | 34.1 | 40.7 | 36.1 | 36.0 |
| **Secondary (refined)** | 198.0 | ^r175.2 | 185.3 | 191.3 | [2]158.9 |
| **Total** | 224.5 | ^r209.3 | 226.0 | 227.4 | 194.9 |
| **United States:** | | | | | |
| **Primary (refined)** | 498.3 | 516.8 | 514.6 | 395.6 | [2]487.4 |
| **Secondary (refined)** | 641.1 | 571.3 | 503.5 | 633.4 | [2]594.2 |
| **Total** | 1,139.4 | 1,088.1 | 1,018.1 | 1,029.0 | [2]1,081.6 |
| **Venezuela**: Secondary (refined) | 12.0 | 15.0 | 15.0 | 17.0 | 18.0 |
| **Yugoslavia:** | | | | | |
| **Primary** | 74.0 | 74.0 | 93.1 | ^r ^e95.0 | 110.0 |
| **Secondary** | 46.5 | 35.0 | 34.0 | 35.0 | 40.0 |
| **Total** | 120.5 | 109.0 | 127.1 | ^r ^e130.0 | 150.0 |
| **Zambia**: Primary (refined) | 9.9 | 14.6 | 14.6 | 8.8 | 9.2 |
| Grand total | ^r5,383.8 | ^r5,295.7 | 5,282.4 | 5,451.8 | 5,526.8 |
| Of which: | | | | | |
| Primary | ^r3,126.4 | ^r3,220.0 | 3,251.4 | 3,180.1 | 3,346.7 |
| Secondary | ^r2,257.4 | ^r2,075.7 | 2,031.0 | 2,271.7 | 2,180.1 |

^eEstimated. ^pPreliminary. ^rRevised.

[1] Table includes data available through June 24, 1986. Figures presented represent, to the extent possible, production of unrefined lead, including bullion and impure lead derived from new and old scrap. The figures for secondary lead for a number of countries are undoubtedly high, but insufficient information is available to separate reprocessed scrap lead from lead merely remelted. Countries for which this is the case have been footnoted. (See footnote 4.) For those countries from which unrefined lead production is not reported, but where available information suggests that there is little if any import or export of bullion for refining and refined lead output has been reported, it is so noted parenthetically because it is believed that the difference between smelter output and refined output is negligible.

[2] Reported figure.

[3] Data not reported, derived from reported primary refined lead output minus imports of lead bullion plus exports of lead bullion and checked against use of lead content of domestically produced ores plus lead content of imported ores (estimated) minus lead content of exported ores (estimated).

[4] Some part of the total entered may be merely remelt, and as such probably should not be included here, but a substantial part of the total presumably was reprocessed to qualify as a secondary smelter product. Available information is inadequate to permit differentiation, and the total has been included, although it is recognized that this produces a slightly inflated figure.

[5] Revised to zero.

[6] Production from Imperial Smelting Furnace at Avonmouth only.

## Table 32.—Lead: World refinery production, by country[1]

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| **Argentina:** | | | | | |
| Primary | 19.0 | 17.0 | 16.0 | [e]19.0 | 18.0 |
| Secondary | 15.6 | 14.6 | 15.0 | [e]17.0 | 16.0 |
| Total | 34.6 | 31.6 | 31.0 | [e]36.0 | 34.0 |
| **Australia:** | | | | | |
| Primary | 207.7 | 218.8 | 196.3 | 198.8 | 196.2 |
| Secondary[e] | 31.5 | 28.3 | [r]27.0 | 21.5 | 15.9 |
| Total | 239.2 | 247.1 | 223.3 | 220.3 | 212.1 |
| **Austria:** | | | | | |
| Primary | [r]5.0 | [r]10.4 | 12.0 | 7.2 | 4.5 |
| Secondary | [r]11.6 | [r]11.1 | 11.5 | 13.4 | 14.7 |
| Total | [r]16.6 | [r]21.5 | 23.5 | 20.6 | 19.2 |
| **Belgium:** | | | | | |
| Primary | 73.9 | 66.0 | 96.3 | 89.6 | 77.6 |
| Secondary | 36.0 | 33.7 | 37.8 | 38.1 | 37.4 |
| Total | 109.9 | 99.7 | 134.1 | 127.7 | 115.0 |
| **Brazil:** | | | | | |
| Primary | 34.7 | 21.9 | 21.0 | 26.0 | 27.0 |
| Secondary | [r]29.0 | [r]26.3 | 29.0 | 37.7 | 40.0 |
| Total | [r]63.7 | [r]48.2 | 50.0 | 63.7 | 67.0 |
| **Bulgaria:**[e] | | | | | |
| Primary | 101.2 | 100.3 | 98.6 | 98.6 | 98.0 |
| Secondary | 17.8 | 17.7 | 17.4 | 17.4 | 18.0 |
| Total | 119.0 | 118.0 | 116.0 | 116.0 | 116.0 |
| **Burma:** | | | | | |
| Primary | 4.1 | 7.8 | 7.6 | 7.0 | [2]9.6 |
| Secondary[e] | (3) | (3) | (3) | (3) | -- |
| Total | 4.1 | 7.8 | 7.6 | 7.0 | 9.6 |
| **Canada:** | | | | | |
| Primary | 168.5 | 174.3 | 178.1 | 173.0 | 172.7 |
| Secondary | 69.7 | 64.6 | 63.9 | 79.0 | 66.8 |
| Total | 238.2 | 238.9 | 242.0 | 252.0 | 239.5 |
| **China:**[e] | | | | | |
| Primary | 150.0 | 155.0 | 165.0 | 165.0 | 165.0 |
| Secondary | 25.0 | 20.0 | 30.0 | 30.0 | 30.0 |
| Total | 175.0 | 175.0 | 195.0 | 195.0 | 195.0 |
| Colombia: Secondary[e] | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Cyprus: Secondary[e] | 2.5 | 2.5 | 2.5 | 2.5 | 2.0 |
| Czechoslovakia: Secondary | 21.0 | 21.0 | 21.0 | 21.1 | 21.5 |
| Denmark: Secondary | 24.0 | 15.9 | 10.0 | 13.0 | [2]4.5 |
| Finland: Secondary | 4.5 | 4.4 | 6.0 | 4.5 | 4.4 |
| **France:** | | | | | |
| Primary | 128.6 | 122.7 | 115.0 | 117.9 | 132.3 |
| Secondary | 99.4 | 85.9 | 99.4 | 88.8 | 98.9 |
| Total | 228.0 | 208.6 | 214.4 | 206.7 | 231.2 |
| German Democratic Republic: Secondary[e] | [r]43.0 | [r]38.0 | [r]36.0 | [r]35.0 | 36.0 |
| **Germany, Federal Republic of:** | | | | | |
| Primary | 189.5 | 201.6 | 217.0 | 191.9 | 193.5 |
| Secondary | 158.8 | 148.9 | 135.5 | 165.3 | 163.0 |
| Total | 348.3 | 350.5 | 352.5 | 357.2 | 356.5 |
| **Greece:** | | | | | |
| Primary | 21.0 | 3.2 | -- | (3) | 15.0 |
| Secondary | 4.0 | -- | -- | -- | -- |
| Total | 25.0 | 3.2 | -- | (3) | 15.0 |
| Guatemala: Secondary | .1 | .1 | .1 | .1 | .1 |
| Hungary: Secondary[e] | .1 | .1 | .1 | .1 | .1 |

See footnotes at end of table.

## Table 32.—Lead: World refinery production, by country[1] —Continued

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| India: | | | | | |
| Primary | 14.3 | [e]14.4 | 15.0 | 15.2 | [2]15.6 |
| Secondary | 11.1 | [e]8.8 | 6.6 | [r] [e]10.0 | 10.0 |
| Total | 25.4 | [e]23.2 | 21.6 | [r] [e]25.2 | 25.6 |
| Ireland: Secondary[e] | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| Italy: | | | | | |
| Primary | 35.6 | 36.4 | 37.0 | 37.6 | [2]29.5 |
| Secondary | 97.4 | 97.3 | 89.4 | 102.9 | 95.0 |
| Total | 133.0 | 133.7 | 126.4 | 140.5 | 124.5 |
| Jamaica: Secondary[e] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Japan: | | | | | |
| Primary | 175.4 | 183.1 | 203.3 | 233.8 | [2]233.7 |
| Secondary | 141.6 | 119.1 | 118.3 | 129.2 | [2]133.3 |
| Total | 317.0 | 302.2 | 321.6 | 363.0 | [2]367.0 |
| Korea, North:[e] | | | | | |
| Primary (refined) | [r]65.0 | [r]60.0 | [r]60.0 | [r]95.0 | 95.0 |
| Secondary | ([3]) | ([3]) | ([3]) | ([3]) | -- |
| Total | 65.0 | 60.0 | 60.0 | [r]95.0 | 95.0 |
| Korea, Republic of:[e] | | | | | |
| Primary | 7.2 | 9.5 | 10.5 | [r]12.0 | 14.5 |
| Secondary | 7.5 | 6.6 | 7.3 | [r]8.3 | 7.9 |
| Total | 14.7 | 16.1 | 17.8 | 20.3 | 22.4 |
| Malaysia: Secondary | [e]3.5 | 3.0 | [e]4.0 | [r] [e]9.0 | 8.8 |
| Mexico: | | | | | |
| Primary | 150.6 | 137.2 | 162.5 | 162.2 | 165.0 |
| Secondary[e] | 38.0 | 34.0 | [r]29.0 | [r]25.0 | 25.0 |
| Total[e] | 188.6 | 171.2 | [r]191.5 | [r]187.2 | 190.0 |
| Morocco: | | | | | |
| Primary | 50.1 | 56.5 | 55.2 | 46.1 | 46.0 |
| Secondary[e] | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 |
| Total[e] | 52.2 | 58.5 | [r]57.2 | 48.1 | 48.0 |
| Namibia: Primary | 41.7 | 40.6 | 35.4 | 28.9 | [2]38.5 |
| Netherlands: | | | | | |
| Primary | ([3]) | [r]4.8 | 2.0 | ([3]) | -- |
| Secondary | [r]33.9 | [r]27.7 | 23.6 | 33.6 | 37.6 |
| Total | 33.9 | [r]32.5 | 25.6 | 33.6 | 37.6 |
| New Zealand: Secondary[e] | 7.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Nigeria: Secondary[e] | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 |
| Pakistan: Secondary[e] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Peru: | | | | | |
| Primary | 79.2 | 77.0 | 67.7 | 70.3 | [2]81.9 |
| Secondary[e] | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Total[e] | 84.2 | 82.0 | 72.7 | 75.3 | 86.9 |
| Philippines: Secondary | 4.0 | 6.0 | 6.0 | 4.0 | 4.0 |
| Poland: | | | | | |
| Primary[e] | 48.3 | 55.2 | 56.7 | 58.4 | 61.1 |
| Secondary[e] | 20.7 | 23.6 | 24.3 | 25.0 | 26.2 |
| Total | 69.0 | 78.8 | 81.0 | 83.4 | [2]87.3 |
| Portugal: Secondary | 5.3 | 4.0 | 6.0 | [e]6.0 | 6.0 |
| Romania: | | | | | |
| Primary[e] | [r] [2]40.7 | 40.5 | 40.0 | 39.0 | 39.0 |
| Secondary[e] | 5.0 | 5.2 | [r]9.3 | 10.0 | 10.0 |
| Total | [r]45.7 | 45.7 | 49.3 | [e]49.0 | 49.0 |
| South Africa, Republic of: Secondary | 26.9 | 30.4 | 23.6 | 21.9 | 20.0 |

See footnotes at end of table.

## Table 32.—Lead: World refinery production, by country[1] —Continued

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Spain: | | | | | |
| Primary | [r]83.0 | 99.5 | 107.8 | 110.1 | 110.0 |
| Secondary | 34.1 | 32.1 | 36.0 | 49.9 | 45.0 |
| Total | [r]117.1 | 131.6 | 143.8 | 160.0 | 155.0 |
| Sweden: | | | | | |
| Primary | 7.0 | 29.6 | 34.8 | 49.8 | 48.6 |
| Secondary | 22.0 | 19.9 | 18.8 | 23.4 | [2]20.0 |
| Total | 29.0 | 49.5 | 53.6 | 73.2 | [2]68.6 |
| Switzerland: Secondary | 4.0 | 3.0 | 2.0 | 2.0 | 2.0 |
| Taiwan: Secondary[e] | 30.0 | 35.0 | 38.0 | [r]44.3 | 44.4 |
| Thailand: Secondary | .5 | .9 | 3.2 | 6.2 | 6.0 |
| Trinidad and Tobago: Secondary[e] | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Tunisia: | | | | | |
| Primary | 17.5 | 15.3 | 10.4 | 8.4 | 10.0 |
| Secondary[e] | .5 | .5 | [r].5 | .5 | .5 |
| Total[e] | 18.0 | 15.8 | [r]10.9 | [r]8.9 | 10.5 |
| Turkey: Primary | [r]2.5 | [r]3.1 | 4.0 | [e]4.0 | 3.6 |
| U.S.S.R.:[e] | | | | | |
| Primary | 480.0 | 485.0 | 490.0 | 495.0 | 495.0 |
| Secondary | 235.0 | 245.0 | 255.0 | 260.0 | 265.0 |
| Total | 715.0 | 730.0 | 745.0 | 755.0 | 760.0 |
| United Kingdom: | | | | | |
| Primary | 135.4 | 131.0 | 136.9 | 147.1 | [2]140.5 |
| Secondary | 198.0 | 175.2 | 185.3 | 191.3 | [2]158.9 |
| Total | 333.4 | 306.2 | 322.2 | 338.4 | [2]299.4 |
| United States: | | | | | |
| Primary | 498.3 | 516.8 | 514.6 | 395.6 | [2]487.4 |
| Secondary | 641.1 | 571.3 | 503.5 | 633.4 | [2]594.2 |
| Total | 1,139.4 | 1,088.1 | 1,018.1 | 1,029.0 | [2]1,081.6 |
| Venezuela: Secondary | [r]12.0 | [r]15.0 | 15.0 | 17.0 | 18.0 |
| Yugoslavia: | | | | | |
| Primary | 73.9 | 72.0 | 54.8 | 45.4 | 62.0 |
| Secondary | 12.5 | 10.2 | 42.7 | 37.4 | 38.0 |
| Total | 86.4 | 82.2 | 97.5 | 82.8 | [2]100.0 |
| Zambia: Primary | 9.9 | 14.6 | 14.6 | 8.8 | 9.2 |
| Grand total | [r]5,330.1 | [r]5,220.0 | 5,257.7 | 5,423.5 | 5,473.6 |
| Of which: | | | | | |
| Primary | [r]3,118.8 | [r]3,181.1 | 3,236.1 | 3,156.7 | 3,295.5 |
| Secondary | [r]2,211.3 | [r]2,038.9 | 2,021.6 | 2,266.8 | 2,178.1 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through June 24, 1986. Data included represent the total output of refined lead by each country, whether derived from ores and concentrates (primary) or scrap (secondary), and include the lead content of antimonial lead, but exclude, to the extent possible, simple remelting of scrap.

[2] Reported figure.

[3] Revised to zero.

# Lime

## By Lawrence Pelham[1]

Lime output, including that for Puerto Rico, was essentially unchanged from that of 1984 at 15.7 million short tons and valued at $812 million.

Output of agricultural lime increased 5%; construction, chemical, and industrial lime was essentially unchanged; and refractory lime decreased 22%.

**Domestic Data Coverage.**—Domestic production data for lime are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Typical of these surveys is the annual "Lime" survey. Of the 116 operations to which the annual survey request was sent, all responded, representing 100% of the total sold or used by producers shown in tables 1 and 2.

**Table 1.—Salient lime statistics**

(Thousand short tons unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States:[1] | | | | | |
| Number of plants | 150 | 147 | 139 | [r]129 | 115 |
| Sold or used by producers: | | | | | |
| Quicklime | 16,142 | 11,701 | 12,383 | 13,134 | 12,997 |
| Hydrated lime | 2,279 | 2,037 | 2,066 | 2,302 | 2,314 |
| Dead-burned dolomite | 435 | 337 | 418 | 487 | 378 |
| Total[2] | 18,856 | 14,075 | 14,867 | 15,922 | 15,690 |
| Value[3] thousands | $884,197 | $696,207 | $757,611 | $811,183 | $809,000 |
| Average value per ton | $46.89 | $49.46 | $50.96 | $50.95 | $51.70 |
| Lime sold | 14,271 | 10,856 | 12,083 | 13,064 | 13,409 |
| Lime used | 4,585 | 3,219 | 2,784 | 2,858 | 2,281 |
| Exports[4] | 28 | 23 | 28 | 25 | 19 |
| Imports for consumption[4] | 504 | 348 | 283 | 247 | 194 |
| Consumption[5] | 19,332 | 14,400 | 15,122 | 16,144 | 15,777 |
| World: Production | 128,921 | 120,364 | 121,919 | [p]125,630 | [e]123,531 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Excludes regenerated lime. Excludes Puerto Rico.

[2]Data may not add to totals shown because of independent rounding.

[3]Selling value, f.o.b. plant, excluding cost of containers.

[4]Bureau of the Census.

[5]Measured by sold or used plus imports minus exports.

## DOMESTIC PRODUCTION

Lime sold or used by producers, including Puerto Rico, was essentially unchanged at 15.7 million tons. Captive lime used by producers decreased 9% to 2.6 million tons.

Production of quicklime and hydrated lime was essentially unchanged at 13.4 million tons and 2.3 million tons, respectively. Production of dead-burned dolomite decreased 22%.

Six States produced over 1 million tons each and accounted for 56% of total lime output. They were, in descending order, Ohio, Kentucky, Missouri, Pennsylvania, Alabama, and Texas. Production increased 5% in Alabama and 7% in Kentucky, and was relatively unchanged in Texas and

Missouri, but decreased 7% in Ohio and 8% in Pennsylvania.

Seventy-five companies produced lime. Leading producing companies, in descending order, were Dravo Lime Co. with one plant each in Alabama, Kentucky, Louisiana, and Texas; Marblehead Lime Co. with two plants in Illinois and one each in Indiana, Michigan, Pennsylvania, and Utah; Mississippi Lime Co. in Missouri; Martin Marietta Corp. in Ohio; Genstar Lime Co. with two plants in California, two plants in Nevada, and one each in Arizona and Utah; Allied Chemical Corp. with two plants in New York; Black River Lime Co. in Kentucky; Allied Products Co. in Alabama; Bethlehem Steel Corp. with two plants in Pennsylvania; and Republic Steel Corp. in Ohio. These 10 companies, operating 25 plants, accounted for 53% of the total lime production.

The number of plants producing lime in the United States and Puerto Rico decreased from 130 (revised) in 1984 to 116 in 1985. Seven lime plants each produced more than 400,000 tons of lime and together accounted for 34% of the total lime output. Leading individual plants, in descending order, were Mississippi Lime's Ste. Genevieve plant in Missouri, Dravo Lime's Maysville plant in Kentucky, Martin Marietta Chemical Div.'s Woodville plant in Ohio, Allied Chemical's Syracuse Works in New York, Marblehead Lime's Buffington plant in Indiana, Black River Lime's Carntown plant in Kentucky, and Marblehead Lime's South Chicago plant in Illinois. Sixteen plants each produced from 200,000 to 400,000 tons of lime and together accounted for 28% of the total.

**New Plants, Expansions, and Changes.**—In February, Ash Grove Cement Co. began operating at its plant in Springfield, MO, a kiln that had been converted from a vertical shaft kiln of English Priest design to the Parsons single-shaft, parallel-flow calciner system. The conversion was made to improve product quality and reduce operating cost. The kiln has a design capacity of 300 tons per day of lime with a fuel efficiency under 4 million British thermal units per ton.[2]

Holly Sugar Corp. installed in Brawley, CA, the first Fuller-Bechkenbach mixed-feed-type shaft kiln to be built in the United States. The mixed-feed-type kiln is one of several Bechkenbach shaft kiln designs licensed by Fuller Co., Bethlehem, PA, from Warmestelle Steine und Erden of Düsseldorf, Federal Republic of Germany. The production quality and fuel efficiency of these kilns are believed to be the highest of any shaft kiln in North America.[3]

Western Lime & Cement Co. began operating a new 250-ton-per-day kiln system at its plant in Marblehead, WI. The new kiln provided a substantial increase in capacity over that of the two shaft kilns it replaced at Marblehead and Knowles, WI, which had a combined output of 180 tons per day, and completed the company's planned fuel conversion from gas to coal.[4]

Florida Crushed Stone Co. continued construction of a 350,000-ton-per-year lime plant near Brooksville, Hernando County, FL.

Fourteen fewer plants reported production in 1985 than in 1984. In California, American Crystal Sugar Co.'s Clarksburg kiln was idle. In Colorado, The Great Western Sugar Co. closed five plants. In Connecticut, Pfizer Inc. had closed permanently its Canaan plant in the first quarter of 1984. In Florida, Ideal Basic Industries Inc. did not operate its Port St. Joe kiln. In Kansas, the Kemp plant of Great Western Sugar was idle, as was its Billings plant in Montana and its Scotts Bluff and Gering plants in Nebraska. In Pennsylvania, the Reedsville plant of Honey Creek Lime Co. was idle. In Texas, the Chemical Lime Co. idled its Marblefall plant.

## Table 2.—Lime sold or used by producers in the United States, by State[1]

| State | 1984 | | | | | 1985 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Plants | Hydrated (thousand short tons) | Quicklime (thousand short tons) | Total[2] (thousand short tons) | Value (thousands) | Plants | Hydrated (thousand short tons) | Quicklime (thousand short tons) | Total[2] (thousand short tons) | Value (thousands) |
| Alabama | 5 | 146 | 1,018 | 1,163 | $50,560 | 5 | 113 | 1,103 | 1,216 | $52,295 |
| Arizona | 3 | -- | 359 | 359 | 17,304 | 3 | W | W | 476 | 21,226 |
| Arkansas, Louisiana, Oklahoma | 4 | 112 | 213 | 325 | 17,635 | 4 | W | W | W | W |
| California | 11 | W | W | 406 | 26,827 | 10 | W | W | 367 | 24,733 |
| Colorado, Nevada, Wyoming | [r]12 | W | W | 230 | 16,674 | 6 | W | W | 188 | 15,398 |
| Connecticut | 1 | -- | W | W | W | -- | -- | -- | -- | -- |
| Florida | 3 | W | W | 171 | 9,379 | 2 | W | W | W | W |
| Hawaii, Oregon, Washington | 5 | [r]26 | [r]330 | [r]357 | 23,539 | 5 | W | W | 356 | 24,318 |
| Idaho | 3 | -- | 87 | 87 | 5,616 | 3 | -- | 93 | 93 | 5,803 |
| Illinois, Indiana, Missouri | 8 | 416 | 2,879 | 3,295 | 155,853 | 8 | 436 | 2,848 | 3,283 | 160,121 |
| Iowa, Kansas (1984), Nebraska, South Dakota | 6 | W | W | 227 | 12,207 | 4 | W | W | W | W |
| Kentucky, New York, Tennessee, West Virginia | 6 | 97 | 2,281 | [r]2,378 | 113,313 | 6 | W | W | 2,489 | 122,644 |
| Maryland | 1 | 4 | 3 | 7 | 419 | 1 | 6 | 3 | 10 | 608 |
| Massachusetts | 2 | 16 | 155 | 171 | 12,426 | 2 | 15 | 144 | 159 | 10,935 |
| Michigan | [r]8 | W | W | 622 | 30,092 | 8 | W | W | 535 | 24,790 |
| Minnesota | 4 | W | W | W | W | 4 | -- | W | W | W |
| Montana | 3 | -- | 89 | 89 | 5,097 | 2 | -- | W | W | W |
| North Dakota | 3 | -- | 59 | [r]59 | 5,912 | 3 | -- | 56 | 56 | 5,562 |
| Ohio | [r]9 | W | W | 1,859 | 87,951 | 9 | W | W | 1,730 | 84,142 |
| Pennsylvania | 10 | 402 | 1,218 | 1,620 | 90,182 | 9 | 344 | 1,148 | 1,492 | 85,269 |
| Puerto Rico | 1 | 35 | -- | 35 | 4,531 | 1 | 23 | -- | 23 | 3,249 |
| Texas | 8 | 555 | 602 | 1,157 | 61,214 | 7 | 587 | 605 | 1,192 | 65,927 |
| Utah | 4 | W | W | 297 | 16,471 | 4 | W | W | 225 | 11,912 |
| Virginia | 5 | 97 | 465 | 562 | 24,799 | 5 | 127 | 506 | 633 | 28,103 |
| Wisconsin | 5 | 105 | 266 | 373 | 19,892 | 5 | 99 | 243 | 341 | 19,001 |
| Other[3] | ([4]) | 324 | 3,596 | 110 | 7,819 | ([4]) | 587 | 6,627 | 846 | 46,214 |
| Total[2] | [r]130 | 2,336 | 13,620 | 15,956 | 815,714 | 116 | 2,337 | 13,376 | 15,713 | 812,249 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Excludes regenerated lime. Includes Puerto Rico.

[2] Data may not add to totals shown because of independent rounding.

[3] Includes States indicated by symbol W.

[4] Included with data for each individual State.

**Table 3.—Lime sold or used by producers in the United States,[1] by size of plant**

| Size of plant | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Plants | Quantity (thousand short tons) | Percent of total | Plants | Quantity (thousand short tons) | Percent of total |
| Less than 10,000 tons | 20 | 115 | 1 | 9 | 54 | ([2]) |
| 10,000 to 25,000 tons | 25 | 423 | 3 | 24 | 409 | 3 |
| 25,000 to 50,000 tons | 18 | 663 | 4 | 16 | 625 | 4 |
| 50,000 to 100,000 tons | [r]20 | 1,723 | 11 | 18 | 1,292 | 8 |
| 100,000 to 200,000 tons | 19 | 2,769 | 17 | 26 | 3,774 | 24 |
| 200,000 to 400,000 tons | [r]22 | 5,668 | 36 | 16 | 4,320 | 28 |
| More than 400,000 tons | 6 | 4,595 | 29 | 7 | 5,239 | 33 |
| Total | [r]130 | 15,956 | [3]100 | 116 | 15,713 | 100 |

[r] Revised.
[1] Excludes regenerated lime. Includes Puerto Rico.
[2] Less than 1/2 unit.
[3] Data do not add to total shown because of independent rounding.

## CONSUMPTION AND USES

Lime was consumed in every State. Leading consuming States, in descending order, were Pennsylvania, Ohio, Indiana, Texas, and Michigan, each of which consumed more than 1 million tons. These five States accounted for 46% of the total lime consumed.

Leading quicklime consuming States, in descending order, were Pennsylvania, Ohio, and Indiana, each of which consumed more than 1 million tons. These three States accounted for 34% of the total quicklime consumed. Leading hydrated lime consuming States, in descending order, were Texas, Pennsylvania, Illinois, and Ohio, each of which consumed more than 100,000 tons. These four States accounted for 45% of the total hydrated lime consumed.

Lime sold or used by producers was for chemical and industrial uses, 88%; construction, 9%; refractories, 2.4%; and agriculture, 0.5%. Captive lime was used mainly in the production of steel in basic oxygen furnaces (BOF), 31%; and for sugar refining, 20%.

Leading individual uses of lime, in decreasing order, were for BOF steel, water purification, sulfur removal from stack gases, paper and pulp, and electric-furnace steel, which together accounted for 58% of the total consumption.

Lime consumption in the steel industry decreased slightly to 5.4 million tons and accounted for 34% of all lime consumed in the United States. Lime used for agriculture increased slightly, whereas lime used in construction and in paper and pulp manufacture remained about the same. Environmental uses of lime continued to increase: Lime used for water purification increased 8%; sulfur removal from stack gases, 9%; sewage treatment, 21%; and mine or plant acid water treatment, 5%.

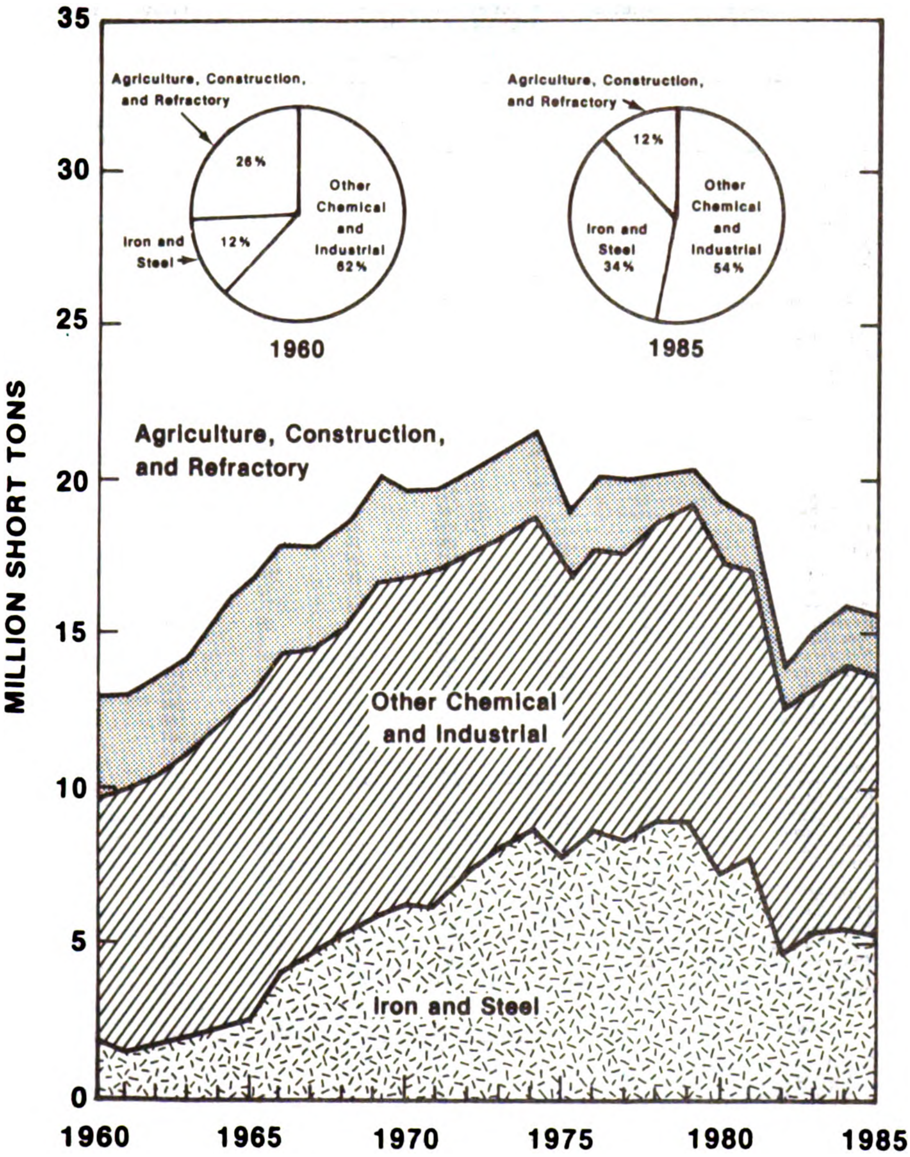

Figure 1.—Trends in major uses of lime.

## Table 4.—Destination of shipments of lime sold or used by producers in the United States, by State[1]

(Thousand short tons)

| State | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Quicklime | Hydrated lime | Total[2] | Quicklime | Hydrated lime | Total[2] |
| Alabama | 370 | 54 | 424 | 437 | 50 | 487 |
| Alaska | (3) | 2 | 2 | (3) | 1 | 1 |
| Arizona | 244 | 32 | 275 | 211 | 61 | 272 |
| Arkansas | 78 | 28 | 106 | 79 | 32 | 111 |
| California | 399 | 84 | 483 | 383 | 87 | 470 |
| Colorado | 95 | 14 | 110 | 63 | 17 | 80 |
| Connecticut | 34 | 10 | 43 | 30 | 10 | 40 |
| Delaware | 37 | 5 | 42 | 30 | 5 | 35 |
| District of Columbia | 13 | 34 | 47 | 17 | 33 | 50 |
| Florida | 373 | 65 | 438 | 375 | 41 | 416 |
| Georgia | 213 | 61 | 274 | 233 | 59 | 292 |
| Hawaii | 4 | 2 | 6 | 5 | 1 | 6 |
| Idaho | 101 | 3 | 104 | 99 | 3 | 102 |
| Illinois | 552 | 112 | 664 | 519 | 137 | 655 |
| Indiana | 1,520 | 41 | 1,562 | 1,483 | 36 | 1,518 |
| Iowa | 73 | 18 | 91 | 75 | 17 | 92 |
| Kansas | 65 | 16 | 81 | 62 | 20 | 82 |
| Kentucky | 471 | 19 | 490 | 534 | 22 | 556 |
| Louisiana | 238 | 127 | 365 | 243 | 118 | 361 |
| Maine | 15 | 1 | 16 | 14 | 3 | 17 |
| Maryland | 241 | 20 | 261 | 266 | 18 | 284 |
| Massachusetts | 67 | 14 | 80 | 62 | 10 | 72 |
| Michigan | 1,165 | 32 | 1,197 | 993 | 33 | 1,026 |
| Minnesota | 190 | 19 | 209 | 183 | 17 | 200 |
| Mississippi | 117 | 28 | 146 | 126 | 28 | 154 |
| Missouri | 148 | 40 | 188 | 141 | 48 | 189 |
| Montana | 62 | 11 | 73 | 33 | 13 | 46 |
| Nebraska | 66 | 5 | 71 | 35 | 6 | 41 |
| Nevada | 72 | 8 | 80 | 86 | 5 | 91 |
| New Hampshire | 3 | 1 | 3 | 2 | (3) | 2 |
| New Jersey | 126 | 61 | 186 | 111 | 52 | 163 |
| New Mexico | 25 | 28 | 53 | 133 | 31 | 164 |
| New York | 631 | 45 | 676 | 634 | 39 | 673 |
| North Carolina | 192 | 24 | 216 | 204 | 30 | 234 |
| North Dakota | 103 | 11 | 114 | 106 | 4 | 110 |
| Ohio | 1,483 | 135 | 1,618 | 1,504 | 121 | 1,625 |
| Oklahoma | 91 | 12 | 104 | 110 | 14 | 124 |
| Oregon | 128 | 15 | 143 | 104 | 12 | 116 |
| Pennsylvania | 1,601 | 234 | 1,835 | 1,558 | 210 | 1,768 |
| Rhode Island | 5 | 2 | 6 | 5 | 2 | 7 |
| South Carolina | 109 | 14 | 123 | 108 | 19 | 128 |
| South Dakota | 12 | 9 | 21 | 25 | 3 | 28 |
| Tennessee | 188 | 77 | 265 | 121 | 120 | 241 |
| Texas | 624 | 548 | 1,172 | 595 | 571 | 1,166 |
| Utah | 270 | 11 | 281 | 210 | 11 | 220 |
| Vermont | (3) | 1 | 1 | (3) | 1 | 1 |
| Virginia | 95 | 55 | 150 | 193 | 21 | 215 |
| Washington | 262 | 14 | 276 | 251 | 12 | 263 |
| West Virginia | 490 | 26 | 516 | 406 | 36 | 441 |
| Wisconsin | 93 | 48 | 141 | 99 | 46 | 146 |
| Wyoming | 43 | 15 | 58 | 56 | 18 | 74 |
| Other[4] | 1 | 24 | 25 | 1 | -- | 1 |
| **Total[2]** | **13,598** | **2,314** | **15,912** | **13,354** | **2,302** | **15,657** |
| **Exports:** | | | | | | |
| **Canada** | **18** | **7** | **25** | **18** | **8** | **26** |
| **Other countries** | **4** | **15** | **19** | **4** | **25** | **29** |
| **Total** | **22** | **22** | **44** | **22** | **33** | **55** |
| **Grand total[2]** | **13,620** | **2,336** | **15,956** | **13,376** | **2,337** | **15,713** |

[1] Excludes regenerated lime. Includes Puerto Rico.
[2] Data may not add to totals shown because of independent rounding.
[3] Less than 1/2 unit.
[4] Includes Puerto Rico and U.S. possessions.

### Table 5.—Lime sold or used by producers in the United States, by use[1]

(Thousand short tons and thousand dollars)

| Use | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Sold | Used | Total[2] | Value | Sold | Used | Total[2] | Value |
| Agriculture | 79 | -- | 79 | 4,848 | 83 | -- | 83 | 5,524 |
| Chemical and industrial: | | | | | | | | |
| Steel, BOF | 3,593 | 797 | 4,390 | 202,015 | 3,369 | 804 | 4,173 | 207,795 |
| Water purification | W | W | 1,401 | 71,978 | W | W | 1,509 | 75,273 |
| Sulfur removal from stack gases | 1,213 | -- | 1,213 | 56,371 | 1,317 | -- | 1,317 | 65,587 |
| Paper and pulp | W | W | 1,135 | 53,811 | W | W | 1,112 | 55,354 |
| Steel, electric | W | W | 929 | 44,167 | W | W | 945 | 47,057 |
| Sewage treatment | W | W | 669 | 36,901 | W | W | 848 | 42,491 |
| Alkalies | W | W | 647 | 31,657 | W | W | 645 | 32,121 |
| Sugar refining | 44 | 573 | 617 | 41,869 | 42 | 514 | 557 | 27,778 |
| Magnesia from seawater or brine | W | W | 564 | 27,586 | W | W | 408 | 10,673 |
| Copper ore concentration | W | W | 367 | 18,288 | W | W | 307 | 15,282 |
| Acid water, mine or plant | W | W | 270 | 14,507 | W | W | 283 | 14,098 |
| Steel, open-hearth | W | W | 256 | 11,043 | W | W | 252 | 12,534 |
| Calcium carbide | W | W | 226 | 9,736 | W | W | 229 | 11,418 |
| Glass | 128 | -- | 128 | 6,172 | 130 | -- | 130 | 6,463 |
| Magnesium metal | W | W | 192 | 12,141 | W | -- | W | W |
| Aluminum and bauxite | 156 | -- | 156 | 8,261 | 112 | -- | 112 | 5,600 |
| Precipitated calcium carbonate | W | W | 131 | 9,118 | W | -- | W | 6,367 |
| Ore concentration, other | 71 | -- | 71 | 3,606 | 82 | -- | 82 | 4,106 |
| Oil and grease | 50 | -- | 50 | 3,049 | 49 | -- | 49 | 2,619 |
| Tanning | 30 | -- | 30 | 1,668 | 40 | -- | 40 | 2,010 |
| Petroleum refining | 29 | -- | 29 | 1,452 | 29 | -- | 29 | 1,437 |
| Food products, animal or human | 39 | -- | 39 | 2,265 | 24 | -- | 24 | 1,209 |
| Oil well drilling | 16 | -- | 16 | 1,092 | 16 | -- | 16 | 1,797 |
| Citric acid | 37 | -- | 37 | 866 | W | -- | W | W |
| Metallurgy, other | 11 | -- | 11 | 505 | 10 | -- | 10 | 513 |
| Fertilizer | 23 | -- | 23 | 1,190 | 6 | -- | 6 | 302 |
| Calcium silicate | 11 | -- | 11 | 599 | -- | -- | -- | -- |
| Gelatin | 5 | -- | 5 | 320 | -- | -- | -- | -- |
| Brick, sand-lime | 4 | (3) | 5 | 274 | 3 | -- | 3 | 186 |
| Paint | 2 | -- | 2 | 163 | 1 | -- | 1 | 62 |
| Other[4] | 5,789 | 1,389 | 391 | 23,063 | 6,224 | 1,098 | 783 | 41,527 |
| Total[2] | 11,252 | 2,759 | 14,011 | 695,733 | 11,454 | 2,416 | 13,870 | 691,660 |
| Construction: | | | | | | | | |
| Road stabilization | 608 | -- | 608 | 33,499 | 601 | -- | 601 | 39,437 |
| Soil stabilization | 243 | -- | 243 | 13,625 | 263 | -- | 263 | 17,275 |
| Mason's lime | W | W | 235 | 14,894 | W | W | 259 | 16,987 |
| Finishing lime | 236 | -- | 236 | 20,424 | 204 | -- | 204 | 13,403 |
| Other[5] | 56 | -- | 56 | 3,299 | 53 | -- | 53 | 3,509 |
| Total[2] | W | W | 1,379 | 85,741 | W | W | 1,381 | 90,611 |
| Refractory dolomite | W | W | 487 | 29,391 | W | W | 378 | 24,454 |
| Grand total[2] | 13,099 | 2,858 | 15,956 | 815,714 | 13,119 | 2,594 | 15,713 | 812,249 |

W Withheld to avoid disclosing company proprietary data.

[1] Excludes regenerated lime. Includes Puerto Rico.

[2] Data may not add to totals shown because of independent rounding.

[3] Less than 1/2 unit.

[4] Includes briquetting, brokers, chrome, commercial hydrators, desiccants, explosives, ferroalloys, fiberglass, glue, insecticides, ladle desulfurizing, manganese, pelletizing, pharmaceuticals, rubber, silica brick, soap, starfish control, wire drawing, unspecified uses, and uses indicated by symbol W in "Chemical and industrial" lime only.

[5] Includes asphalt antistripping.

## PRICES

The average value of lime sold or used by producers, as reported to the Bureau of Mines on an f.o.b.-plant basis, was essentially unchanged at $51.69 per ton. Values were $49.87 for chemical and industrial lime, $64.69 for refractory dolomite, $65.61 for construction lime, and $66.55 for lime used in agriculture.

The average value of quicklime sold was essentially unchanged at $46.46 per ton. Values were $45.88 for chemical lime, $49.02 for lime used in agriculture, $54.88 for construction lime, and $60.24 for refractory dead-burned dolomite.

The average value of hydrated lime sold increased less than $2.00 to $67.56 per ton. Values were $65.96 for both chemical lime and lime used in agriculture and $69.32 for construction lime.

## FOREIGN TRADE

U.S. exports of lime decreased 22% to 19,400 tons. Of the total exports, Canada received 79%, Guyana received 6%, and Mexico received 5%. The remaining 10% went to 33 countries.

Imports, principally from Canada, 84%, and Mexico, 16%, were 194,057 tons, a decrease of 22%.

**Table 6.—U.S. exports of lime**

| | Quantity (short tons) | Value (thousands) |
|---|---|---|
| 1982 | 22,541 | $3,199 |
| 1983 | 28,154 | 4,815 |
| 1984 | 24,714 | 6,805 |
| 1985 | 19,383 | 5,155 |

Source: Bureau of the Census.

**Table 7.—U.S. imports for consumption of lime**

| | Hydrated lime | | Other lime | | Total | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1982 | 60,108 | $3,305 | 288,266 | $13,503 | 348,374 | $16,808 |
| 1983 | 58,811 | 3,431 | 223,752 | 11,345 | 282,563 | 14,776 |
| 1984 | 59,906 | 3,669 | 187,579 | 9,722 | [1]247,484 | 13,391 |
| 1985 | 48,827 | 3,407 | 145,230 | 8,810 | 194,057 | 12,217 |

[1]Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

**Canada.**—The Government agency Department of Energy, Mines and Resources, Ottawa, Canada, reported preliminary statistics on Canadian lime production at 2.2 million tons valued at $137 million. Of the total, 2.0 million tons was quicklime and 0.2 million tons was hydrated lime. Canada imported 17,500 tons of lime from the United States and exported 158,000 tons, primarily to the United States. The principal consumers of lime in Canada were the steel, paper and pulp, and mining industries. Markets for lime use in environmental control were insignificant.

**Japan.**—Total lime production in Japan was approximately 10.5 million tons in 1984, including 8.5 million tons of quicklime and 2.0 million tons of hydrated lime. Usage was 53% for iron and steel manufacture, 26% for chemical purposes, 10% for construction and agriculture, and 11% for other uses. Since 1979, lime had been used in Japan as a "nonexplosive demolition agent." An example of this use was in the demolition of old buildings; rock and concrete structures were broken without using any explosives. In iron and steel manufacture, preliminary treatment of melting pig iron became more common, employing a lime flux for desilication, desulfurization, and dephosphorization.

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[1]Physical scientist, Division of Industrial Minerals.

[2]Pit & Quarry. V. 77, No. 11, 1985, pp. 82-84.

[3]Dorman, W. D. Holly Sugar Sets New Shaft Kiln Standards. Pit & Quarry, v. 77, No. 11, 1985, pp. 54-56.

[4]Herod, S. Western Lime & Cement Starts New Chapter in its Growth Record. Pit & Quarry, v. 77, No. 11, 1985, pp. 41-43.

## Table 8.—Quicklime and hydrated lime, including dead-burned dolomite: World production, by country[1]

(Thousand short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria[e] | 45 | 45 | 45 | 45 | 45 |
| Australia[3] | 964 | [e]1,045 | 1,120 | [e]1,100 | 1,100 |
| Austria | 1,140 | 1,132 | 1,257 | 1,391 | 1,430 |
| Belgium | 2,372 | 1,683 | 1,951 | 2,392 | 1,540 |
| Brazil[e] | 5,500 | 5,500 | 5,500 | 5,500 | 5,500 |
| Bulgaria | 1,938 | 1,958 | 1,801 | 1,682 | 1,760 |
| Burundi | ([4]) | ([4]) | ([4]) | ([4]) | ([4]) |
| Canada | 2,816 | 2,422 | 2,460 | 2,498 | [5]2,200 |
| Chile | 714 | 711 | 797 | 858 | 880 |
| Colombia[e] | 1,430 | 1,430 | 1,430 | 1,430 | 1,430 |
| Costa Rica[e] | 8 | 10 | 11 | 11 | 11 |
| Cuba | 154 | [r]161 | 169 | 166 | 165 |
| Cyprus | 12 | [r]12 | 9 | [e]9 | 8 |
| Czechoslovakia | 3,565 | 3,404 | 3,417 | 3,436 | [5]3,557 |
| Denmark (sales) | [r]109 | 109 | 119 | 141 | 142 |
| Dominican Republic[e] | 44 | 44 | 44 | 44 | 44 |
| Egypt | 101 | [e]105 | 103 | [e]107 | 107 |
| Fiji Islands | 5 | 4 | [e]3 | [e]3 | 3 |
| Finland | 422 | 396 | 379 | [e]390 | 390 |
| France | 3,710 | 3,300 | 3,247 | 3,450 | 3,300 |
| German Democratic Republic | 3,793 | 3,869 | 3,812 | 3,965 | 4,000 |
| Germany, Federal Republic of | 8,726 | 7,604 | 7,574 | 7,651 | 7,700 |
| Guatemala | 27 | [e]27 | 30 | 56 | 56 |
| Hungary | 834 | [r]932 | 906 | 907 | [5]880 |
| India[e] | 440 | 440 | 440 | [r]550 | 550 |
| Iran[e] | 550 | 600 | 700 | 700 | 700 |
| Ireland | 51 | 51 | [r] [e]65 | 75 | 80 |
| Israel | 88 | 55 | 45 | [e]55 | 55 |
| Italy | 2,543 | 2,389 | 2,228 | [e]2,300 | 2,200 |
| Jamaica | 146 | 126 | 134 | 127 | 127 |
| Japan (quicklime only) | 8,848 | 8,573 | 8,197 | 8,547 | 8,160 |
| Jordan | 22 | 66 | 294 | 247 | 247 |
| Kenya | [e]30 | 24 | 38 | 23 | 40 |
| Korea, Republic of[e] | 220 | 220 | 220 | 220 | 220 |
| Kuwait | 24 | 11 | [r] [e]15 | 17 | 17 |
| Lebanon | [5]67 | 55 | 22 | 11 | 11 |
| Libya | 259 | 248 | 287 | [e]287 | 300 |
| Malawi | ([4]) | 2 | 2 | 2 | 2 |
| Malta | 7 | 8 | 6 | [e]6 | 6 |
| Martinique[e] | [5]6 | 6 | 6 | 6 | 6 |
| Mauritius | 8 | 8 | [e]8 | [e]8 | 8 |
| Mexico[e] | [5]4,960 | 4,400 | 4,000 | 4,400 | 4,400 |
| Mongolia[e] | 55 | 65 | 70 | 72 | 80 |
| Mozambique[e] | 11 | 11 | 11 | 11 | 11 |
| Nepal[e] | 11 | 11 | 11 | [5]8 | [5] [7]8 |
| New Zealand[e] | 190 | 190 | 180 | 165 | 175 |
| Nicaragua[e] | 33 | 6 | [5]5 | 3 | [5]4 |
| Norway[e] | 145 | 145 | 145 | 145 | 110 |
| Paraguay | 63 | 59 | 81 | 94 | 90 |
| Peru[e] | [5]37 | 40 | 40 | 40 | 40 |
| Philippines | 94 | 73 | 56 | 55 | 50 |
| Poland | 4,607 | 4,476 | 4,543 | 4,686 | 4,500 |
| Portugal[e] | [r] [5]300 | [r]275 | 250 | 220 | 230 |
| Romania | 4,125 | 4,180 | 3,994 | [e]4,100 | 4,100 |
| Saudi Arabia[e] | 190 | [r]190 | 10 | [r]12 | 13 |
| South Africa, Republic of (sales) | 2,380 | 2,232 | 2,085 | 2,325 | [5]2,220 |
| Spain | 1,158 | [e]1,200 | [e]1,100 | 1,199 | 1,200 |
| Sweden | [r]718 | [r]649 | 681 | [r] [e]680 | 680 |
| Switzerland | 63 | 51 | 47 | 45 | 45 |
| Taiwan | [r]198 | [r]152 | 145 | 130 | 115 |
| Tanzania[e] | 7 | 7 | [5]3 | 3 | 3 |
| Tunisia | 514 | [e]550 | 640 | [e]660 | 660 |
| Turkey | 1,000 | 1,000 | 1,100 | [e]1,100 | 1,100 |
| Uganda | [r]93 | [r]82 | 455 | [r] [e]550 | 550 |
| U.S.S.R | 31,306 | 31,636 | 32,520 | 32,520 | 32,520 |
| United Arab Emirates[e] | 45 | 45 | 50 | 50 | 50 |
| United Kingdom[e] | [r]2,750 | [r]2,750 | [r]2,750 | [r]2,750 | 2,750 |
| United States including Puerto Rico (sold or used by producers) | 18,890 | 14,112 | 14,902 | 15,956 | [5]15,713 |
| Uruguay | [e]55 | 15 | 11 | 9 | 9 |
| Venezuela | 2 | 2 | [e]2 | [e]2 | 2 |

See footnotes at end of table.

### Table 8.—Quicklime and hydrated lime, including dead-burned dolomite: World production, by country[1] —Continued

(Thousand short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Yugoslavia | 2,826 | 2,657 | 2,810 | [r] [e]2,850 | 2,750 |
| Zaire | 136 | 114 | 118 | 121 | 121 |
| Zambia | 221 | 204 | 213 | 256 | 255 |
| Total | [r]128,921 | [r]120,364 | 121,919 | 125,630 | 123,531 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Table includes data available through June 24, 1986.

[2] Lime is produced in many other countries besides those listed. Argentina, China, Iraq, Pakistan, and Syria are among the more important countries for which official data are not available.

[3] Data are for years ending June 30 of that stated.

[4] Less than 1/2 unit.

[5] Reported figure.

[6] Revised to "Not available." General information is inadequate to formulate a reliable estimate of output, if any.

[7] Data are for year ending mid-July of that stated.

# Lithium

## By James P. Searls[1]

The United States remained the world's largest producer of lithium minerals and chemicals, although the two domestic producers reduced production. Estimated consumption declined, despite a very significant increase in imports, primarily because of a decrease in demand for lithium carbonate by the aluminum smelting industry. Exports also decreased, and producers' stocks increased. Estimated world production increased because of significant increases in Australian and Canadian production of lithium ores and Chilean production of lithium carbonate from brines.

**Domestic Data Coverage.**—Domestic production data for lithium are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the two operations to which a survey request was sent, both responded, representing 100% of total production. However, production and stock data were withheld from publication to avoid disclosing company proprietary data.

**Table 1.—Salient lithium statistics**

(Short tons of contained lithium)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production[1] | W | W | W | W | W |
| Producers' stock changes[1] | W | W | W | W | W |
| Imports[2] | 150 | 30 | 35 | 90 | 410 |
| Shipments of Government stockpile surplus[3] | -- | 2 | 1 | 1 | 1 |
| Supply[1] [4] | 6,900 | 5,000 | 6,000 | 6,600 | 5,500 |
| Supply[e] [5] | 5,800 | 4,300 | 4,300 | 6,100 | 5,000 |
| Exports[e] [6] | 2,600 | 2,300 | 2,600 | 2,900 | 2,500 |
| Consumption: | | | | | |
| Apparent | W | W | W | W | W |
| Estimated | 3,200 | 2,000 | 2,200 | 3,200 | 2,500 |
| Rest of world: Production[e] [1] | 2,800 | 2,600 | 2,600 | 3,300 | 3,600 |

[e] Estimated. W Withheld to avoid disclosing company proprietary data.

[1] Mineral concentrate and carbonate.

[2] Compounds, concentrate, ores, and metal.

[3] Lithium hydroxide monohydrate.

[4] Production minus inventory increase.

[5] Based primarily on monitoring at the carbonate stage and assuming a 15% lithium loss during conversion of concentrate to chemicals.

[6] Compounds.

**Legislation and Government Programs.**—The General Services Administration reported four sales of lithium hydroxide monohydrate from excess stocks in the National Defense Stockpile. This material was excess from a 1960's nuclear weapons program. The stockpile originally contained 46,000 short tons of material, about 75% of which was depleted of lithium 6 and possibly contained 8 to 9 parts per million of mercury. In 1985, 8 tons of depleted material was sold. At yearend, one account contained 15,885 pounds of depleted material, and a second account contained 11,500 tons of virgin material and 28,448 tons of depleted material, for a total of 39,956 tons of material.

## DOMESTIC PRODUCTION

Two companies continued to produce lithium products in the United States. Foote Mineral Co., 87.5% owned by Newmont Mining Corp., mined lithium ore from a pegmatite dike in North Carolina. The ore was purified and converted to lithium carbonate and related lithium compounds. Foote also produced lithium compounds from subsurface brines in Nevada. Lithium Corp. of America (Lithco), owned by Gulf Resources & Chemical Corp. at the beginning of the year, mined lithium ore from a pegmatite dike in North Carolina. On July 19, Gulf Resources sold Lithco to FMC Corp.

Foote reported total domestic production of 9,230 tons of lithium carbonate equivalent, or 1,735 tons of contained lithium, a decrease of about 30%.[2] Foote produced downstream lithium chemicals, metal, and related products in Frazer, PA; Sunbright, VA; and New Johnsonville, TN.

## CONSUMPTION AND USES

Major consumers of lithium minerals and chemicals were the aluminum, ceramics and glass, grease, and synthetic rubber industries. These markets were related primarily to transportation, i.e., the aircraft and automotive industries. Ceramics and glass were also used in industrial and consumer applications. The decrease in estimated consumption of lithium minerals and chemicals was due primarily to permanently reduced activity in the aluminum smelting industry.

The addition of lithium carbonate to the cryolite bath in aluminum potlines was the largest end use for lithium. The lithium carbonate converts to lithium fluoride, which lowers the melting point of the bath, allowing a lower operating pot temperature, as well as increasing the electrical conductivity of the bath. These changes allowed more flexibility to the operators of the potlines to either increase production, reduce power consumption, or increase current efficiency.

As an additive in ceramics and glass, the second largest end use, lithium lowers melting points, reduces the coefficient of thermal expansion, and replaces toxic compounds. The largest ceramics end use was in the manufacture of thermal-shock-resistant cookware. Low-iron petalite and spodumene were used for both their lithia ($LiO_2$) and alumina ($Al_2O_3$) contents.

Lithium-based greases, the third largest end use, were the preferred greases for many uses because of their low hardening point, high dropping point, and good water resistance. They were used extensively in military, industrial, automotive, aircraft, and marine applications.

Aluminum-lithium alloys were used experimentally in 1985 and had potential for greater use in the aircraft and aerospace industries because of their mechanical properties. These alloys contained 2% to 3% lithium and offered lower density, a higher elastic modulus, and excellent corrosion resistance compared with that of conventional aluminum alloys. A French firm was arranging financing for an aluminum-lithium plant at yearend. The British subsidiary of a U.S. firm announced plans to increase its lithium metal production capacity while a British aerospace firm had plans for a prototype aircraft with unspecified components of aluminum-lithium. This group of alloys face active competition from the composite materials, which use such materials as boron, graphite, or aramid fibers imbedded in plastic.

Lithium batteries, in several forms, were competing with other types of batteries in both the primary (nonrechargeable) and secondary (rechargeable) markets.

Anhydrous lithium chloride was used as a feedstock material to prepare lithium metal. Small quantities of lithium were consumed in the form of butyllithium, which was a catalyst in synthetic rubber production, and as lithium hypochlorite, which was a sanitizing agent in the food processing and bottling industries, as well as in swimming pools. Other small consumption but important lithium end uses included lithium carbonate prescribed for treatment of manic-depressive mental disorder, lithium acetate dihydrate as an ester interchange catalyst in polyester production, and lithium metal as a gas scavenger in speciality copper and copper alloy melts.

## STOCKS

Yearend producers' stocks of both lithium carbonate and marketable ore increased moderately.

## PRICES

Prices for the large-volume lithium products, lithium carbonate and lithium hydroxide monohydrate, declined during the year.

### Table 2.—Domestic yearend producers' prices of lithium and lithium compounds

(Dollars per pound)

| | 1984 | 1985 |
|---|---|---|
| Lithium bromide, 54% brine: 2,268-pound lots, delivered in drums | 4.06 | 3.92 |
| Lithium carbonate, technical: Truckload lots, delivered | 1.54 | 1.50 |
| Lithium chloride, anhydrous, technical: Truckload lots, delivered | 3.32 | 3.32 |
| Lithium fluoride | 4.90 | 4.96 |
| Lithium hydroxide monohydrate: Truckload lots, delivered | 1.98 | 1.93 |
| Lithium metal ingot, battery-grade: 1,000-pound lots, f.o.b | 32.50 | 32.50 |
| Lithium metal ingot, standard-grade: 1,000-pound lots, f.o.b | 22.70 | 24.20 |
| Lithium sulfate, anhydrous | 3.09 | 3.21 |
| N-butyllithium in n-hexane (15%): 3,000-pound lots, delivered | 14.75 | 15.10 |

Source: U.S. lithium producers.

## FOREIGN TRADE

U.S. exports of lithium carbonate decreased 23%, owing to the entrance onto the world market of the Chilean capacity in the middle of 1984. Exports of lithium hydroxide and other lithium compounds were essentially unchanged.

U.S. imports, relative to those of 1984, displayed some large changes. Imports of petalite from Zimbabwe increased by more than four orders of magnitude, and imports of spodumene from Canada increased by over 13 times. Imports of lithium carbonate from Chile increased by 262%. Lithium metal was imported from the United Kingdom for the first time.

### Table 3.—U.S. exports of lithium chemicals, by compound and country

| Compound and country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Gross weight (pounds) | Value | Gross weight (pounds) | Value |
| Lithium carbonate: | | | | |
| Argentina | 57,200 | $85,730 | -- | -- |
| Brazil | 83,039 | 114,949 | 264,475 | $341,203 |
| Canada | 1,238,183 | 1,941,641 | 1,898,790 | 2,964,347 |
| Colombia | -- | -- | 2,000 | 4,240 |
| France | -- | -- | 39,600 | 97,218 |
| Germany, Federal Republic of | 8,819,070 | 10,954,569 | 3,921,495 | 4,862,449 |
| India | 33,050 | 52,121 | 25,866 | 40,465 |
| Japan | 4,691,902 | 6,803,317 | 5,611,356 | 7,709,487 |
| Korea, Republic of | 154,822 | 216,578 | 210,937 | 239,644 |
| Mexico | 431,520 | 633,692 | 377,181 | 548,249 |
| Netherlands | 132,000 | 174,240 | 153,974 | 199,590 |
| New Zealand | 31,240 | 51,154 | 26,409 | 55,075 |
| South Africa, Republic of | 46,205 | 69,180 | 80,609 | 129,384 |
| Taiwan | 139,592 | 219,464 | 204,250 | 276,050 |
| United Arab Emirates | 264,022 | 406,108 | 40,000 | 65,200 |
| United Kingdom | 154,013 | 213,767 | 22,000 | 29,260 |
| Venezuela | 1,748,006 | 2,476,585 | 1,037,414 | 1,444,475 |
| Other | $^{r}$44,672 | $^{r}$73,860 | -- | -- |
| Total | 18,068,536 | 24,486,955 | 13,916,356 | 19,006,336 |
| Lithium hydroxide: | | | | |
| Argentina | 430,312 | 766,887 | 67,813 | 123,412 |
| Australia | 102,400 | 183,440 | 319,380 | 608,218 |
| Bahamas | -- | -- | 926 | 1,250 |
| Belgium | 70,400 | 126,720 | 165,440 | 297,792 |
| Brazil | 709,068 | 1,229,638 | 855,313 | 1,535,846 |
| Canada | 4,225 | 8,758 | 5,622 | 9,899 |

See footnotes at end of table.

### Table 3.—U.S. exports of lithium chemicals, by compound and country —Continued

| Compound and country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Gross weight (pounds) | Value | Gross weight (pounds) | Value |
| **Lithium hydroxide —Continued** |  |  |  |  |
| Chile | 76,084 | $158,111 | 29,544 | $54,053 |
| Colombia | 26,750 | 47,811 | 140,275 | 257,198 |
| Ecuador | 16,191 | 32,576 | 4,409 | 8,112 |
| France | 162,800 | 315,400 | 86,857 | 156,940 |
| Germany, Federal Republic of | 1,397,344 | 2,273,650 | 1,356,448 | 2,162,298 |
| Honduras | 4,400 | 9,020 | 2,075 | 4,510 |
| India | 440,291 | 612,000 | 331,778 | 555,031 |
| Indonesia | 135,000 | 285,492 | 75,000 | 158,529 |
| Iran | -- | -- | 4,409 | 8,025 |
| Israel | 45,686 | 80,949 | 12,043 | 21,219 |
| Italy | 22,000 | 39,600 | -- | -- |
| Japan | 1,899,638 | 3,143,978 | 1,741,088 | 3,044,939 |
| Kenya | -- | -- | 18,238 | 54,330 |
| Korea, Republic of | 110,994 | 169,145 | 116,582 | 216,221 |
| Malaysia | 3,799 | 7,024 | 4,200 | 7,686 |
| Mexico | 405,954 | 728,345 | 534,586 | 970,551 |
| Netherlands | 610,860 | 1,086,390 | 341,230 | 602,616 |
| New Zealand | 20,940 | 34,533 | 6,614 | 13,170 |
| Nigeria | -- | -- | 9,240 | 16,203 |
| Pakistan | 44,267 | 87,701 | 25,312 | 41,321 |
| Peru | -- | -- | 26,738 | 43,384 |
| Philippines | 67,100 | 116,413 | 75,633 | 136,322 |
| Saudi Arabia | -- | -- | 11,000 | 20,500 |
| Singapore | 101,411 | 190,720 | 118,948 | 216,297 |
| South Africa, Republic of | 149,610 | 297,187 | 259,678 | 460,063 |
| Spain | 118,800 | 207,840 | 156,200 | 262,108 |
| Taiwan | 91,172 | 144,586 | 74,996 | 134,082 |
| Thailand | 26,781 | 49,388 | 16,066 | 26,839 |
| United Arab Emirates | -- | -- | 8,576 | 15,750 |
| United Kingdom | 776,283 | 1,445,110 | 731,748 | 1,249,180 |
| Venezuela | 78,372 | 139,726 | 88,559 | 160,032 |
| Yugoslavia | 1,102 | 1,985 | 30,864 | 55,560 |
| Other | [r]47,920 | [r]87,532 | -- | -- |
| Total | 8,197,954 | 14,107,655 | 7,853,428 | 13,709,486 |
| **Other:** |  |  |  |  |
| Argentina | 143 | 757 | 6,118 | 22,961 |
| Australia | 29,485 | 64,814 | 10,222 | 24,194 |
| Austria | -- | -- | 24,428 | 42,750 |
| Belgium | 2,160 | 4,578 | 530 | 64,224 |
| Brazil | 29,721 | 63,924 | 51,221 | 86,941 |
| Canada | 844,280 | 1,372,335 | 940,596 | 1,910,884 |
| Chile | 9,825 | 33,980 | 3,968 | 8,478 |
| China | -- | -- | 27,143 | 47,500 |
| Colombia | 13,274 | 25,255 | 7,584 | 12,637 |
| Costa Rica | -- | -- | 527 | 1,130 |
| Denmark | 2,485 | 30,033 | 5,830 | 4,628 |
| France | 33,384 | 94,588 | 42,822 | 171,826 |
| Germany, Federal Republic of | 879,079 | 1,277,981 | 883,906 | 1,241,254 |
| India | 3,086 | 13,401 | 1,096 | 1,700 |
| Israel | 5,235 | 139,984 | 1,687 | 46,075 |
| Italy | 23,255 | 43,357 | 6,157 | 12,085 |
| Japan | 986,107 | 2,006,854 | 530,978 | 1,653,141 |
| Jordan | -- | -- | 15,000 | 15,000 |
| Korea, Republic of | 133,861 | 203,754 | 83,768 | 118,083 |
| Liberia | -- | -- | 10,079 | 11,631 |
| Libya | -- | -- | 5,270 | 7,300 |
| Mexico | 67,131 | 126,307 | 324,759 | 684,533 |
| Netherlands | 219,641 | 279,400 | 181,357 | 242,981 |
| Pakistan | 26,734 | 47,420 | 52,575 | 89,530 |
| Saudi Arabia | 27 | 6,310 | 8,000 | 15,488 |
| Singapore | -- | -- | 11,983 | 31,827 |
| South Africa, Republic of | 8,999 | 31,136 | 5,675 | 9,309 |
| Spain | 4,772 | 4,198 | -- | -- |
| Switzerland | -- | -- | 6,500 | 834,000 |
| Taiwan | 121,150 | 170,540 | 3,647 | 31,740 |
| Turkey | 7,962 | 23,361 | -- | -- |
| United Arab Emirates | -- | -- | 6,360 | 5,049 |
| United Kingdom | 1,943,834 | 3,502,675 | 2,338,742 | 4,878,809 |
| Venezuela | 22,570 | 30,287 | 9,640 | 52,334 |
| Yugoslavia | 198 | 65,676 | 215 | 73,000 |
| Other | [r]12,050 | [r]41,751 | -- | -- |
| Total | 5,430,448 | 9,764,656 | 5,608,383 | 12,453,022 |

[r] Revised.

Source: Bureau of the Census.

Table 4.—U.S. imports for consumption of lithium-bearing materials, by commodity and country

| Commodity and country | 1984 Gross weight (pounds) | 1984 Value (thousands) Customs | 1984 Value (thousands) C.i.f. | 1985 Gross weight (pounds) | 1985 Value (thousands) Customs | 1985 Value (thousands) C.i.f. |
|---|---|---|---|---|---|---|
| Lithium ores: | | | | | | |
| Australia[1] | 119,049 | $15 | $20 | 164,794 | $20 | $23 |
| Canada[1] | 180,000 | 9 | 9 | 2,596,545 | 314 | 314 |
| Peru | 62 | 1 | 1 | -- | -- | -- |
| Zimbabwe | 124 | 3 | 3 | 6,670,868 | 841 | 940 |
| Total | r299,235 | r28 | r33 | 9,432,207 | 1,175 | 1,277 |
| Lithium compounds: | | | | | | |
| Australia | 4,198 | 35 | 39 | -- | -- | -- |
| Belgium | 2,197 | 6 | 7 | 4,933 | 4 | 4 |
| Canada | 3,425 | 36 | 36 | -- | -- | -- |
| Chile | 750,014 | 842 | 891 | 2,713,783 | 3,468 | 3,655 |
| China | 100,200 | 138 | 151 | 18 | 1 | 2 |
| Denmark | 50 | 3 | 3 | -- | -- | -- |
| France | 6,131 | 765 | 770 | 13,820 | 1,712 | 1,722 |
| Germany, Federal Republic of | 42,594 | 292 | 305 | 45,503 | 150 | 160 |
| Japan | 91 | 25 | 26 | 3,379 | 137 | 141 |
| Mexico | 15 | 1 | 1 | -- | -- | -- |
| Switzerland | 15 | (2) | (2) | -- | -- | -- |
| United Kingdom | 15,117 | 81 | 85 | 21,923 | 85 | 90 |
| Total[3] | 924,047 | 2,226 | 2,313 | 2,803,359 | 5,557 | 5,774 |
| Lithium salts: | | | | | | |
| Chile | 220 | (2) | 1 | -- | -- | -- |
| France | 1 | (2) | (2) | -- | -- | -- |
| Germany, Federal Republic of | 9 | 4 | 4 | -- | -- | -- |
| Japan | 1 | (2) | (2) | -- | -- | -- |
| Total[3] | 231 | 5 | 5 | -- | -- | -- |
| Lithium metal: | | | | | | |
| Germany, Federal Republic of | 334 | 12 | 12 | 100 | 4 | 4 |
| United Kingdom | -- | -- | -- | 41,503 | 456 | 466 |
| Total | 334 | 12 | 12 | 41,603 | 460 | 470 |

rRevised.

[1] Spodumene concentrate.

[2] Less than 1/2 unit.

[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census as adjusted by the Bureau of Mines.

## WORLD REVIEW

The separate owners of two high-grade, low-iron spodumene deposits were considering adding lithium carbonate plants at the minesites, in Canada and Australia, during the year. Also, three brine resources in South America were being considered for lithium carbonate production, given the success of the first brine operation in Chile. It was not clear, as the year ended, whether future demand would be sufficient to justify the development of additional lithium carbonate supplies.

**Australia.**—A feasibility study was expected to be completed by January 1986 on a proposed 11-million-pound-per-year $Li_2CO_3$ plant that would use Greenbushes Tin Ltd. (GTL) spodumene as the raw material. A 15-year initial mining plan was developed, based on spodumene reserves of 3.3 million tons containing 4.0% $Li_2O$. The joint venture partners, GTL, Metallgesellschaft AG, and C. Itoh & Co. Ltd., were expected to reach a decision in mid-1986.[3] Meanwhile, GTL was exporting low-iron spodumene to the ceramics and glass industries.

**Austria.**—Mineral Exploration GmbH continued exploration of the Koralpe pegmatite deposit. Reserve estimates increased to 11 million tons of spodumene grading 1.6% $Li_2O$.[4] Flotation tests demonstrated that concentrates of 6% $Li_2O$ could be obtained.

**Bolivia.**—The Bolivian Congress created a state agency, Complejo Industrial de los Recursos Evaporíticos del Salar de Uyuni (CIRESU), to manage development of the Salar de Uyuni, a potential source of lithium, potassium, and boron compounds.[5] CIRESU was authorized to explore, exploit, industrialize, and market through contracts, joint ventures, and partnerships. Drilling was also scheduled for the Laguna Colorda area in the southwestern corner, near the Chilean border, to outline a geothermal resource as an electricity generating site. This potential source of electricity, required for any industrialization of the Salar de Uyuni, is about 150 kilometers south of the salar. The $11.5 million funding for the drilling was supplied by the United Nations Development Program and the Government of Italy.

**Canada.**—In 1984, the Tantalum Mining Corp. of Canada Ltd. (TANCO) began producing a low-iron ceramic-grade spodumene concentrate. In 1985, TANCO started construction of a $6.4 million ore processing plant at its Bernic Lake, Manitoba, mine.[6] The plant, with design capacity of 22,000 tons per year of spodumene concentrate, was scheduled to be finished in mid-1986.

**Chile.**—The Government-owned Corporación de Fomento de la Producción (CORFO), Molibdenos y Metales S.A. (a private Chilean firm), and AMAX Inc. (a multinational U.S. firm) formed a joint venture, Minera Salar de Atacama (MINSAL), to study the feasibility of a second production site on the Salar de Atacama.[7] Initial production of potash and boric acid was proposed pending expiration of Foote's exclusive right to produce lithium carbonate. The Foote and CORFO joint venture, Sociedad Chilena de Litio Ltda., completed its first full year of lithium carbonate production and announced plans to study the feasibility of increasing capacity to 20 million pounds per year.[8]

**France.**—Pechiney obtained financing for its planned aluminum-lithium alloy plant near Issoire, south of Clermont-Ferrand.[9] The facility was planned to produce 3,800 tons per year of alloys starting in 1987.

**Japan.**—Lithco entered into a joint venture with Honjo Chemical Co. for the manufacture of lithium chemicals in Japan.[10] Since 1960, the companies had cooperated in marketing U.S. produced lithium chemicals to Japan. Initial production of n-butyllithium was expected in mid-1986, with other products to be added as required.

**United Kingdom.**—Lithium Corp. of Europe, a subsidiary of Lithco, announced an expansion of production capacity for lithium chloride and metallic lithium at the Liverpool (Bromborough) plant.[11] The expansion anticipated growth in demand, primarily from the aircraft industry, for aluminum-lithium alloys. British Aerospace Ltd. planned to have an experimental craft with aluminum-lithium components in the air in 1986.[12] The experiment is a first step toward development of the "European Fighter Aircraft," a five-country program for joint production and use by 1995. The A-5J *Vigilante* of the U.S. Navy was the first airplane built with aluminum-lithium skin on its wings for weight reduction.

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[1] Physical scientist, Division of Industrial Minerals.

[2] Foote Mineral Co. 1985 10-K Report. FMC Corp., the new owner of Lithco, did not report specific lithium data in its 1985 10-K report.

[3] Greenbushes Tin Ltd. (Australia). Quarterly Report. Fourth quarter ending June 30, 1985, p. 2.

[4] Mining Magazine. Mining in Austria. V. 153, No. 4, 1985, p. 294.

[5] ———. Bolivian Geothermal Project. V. 153, No. 2, 1985, p. 89.

[6] Metal Bulletin (London). TANCO To Reopen—But Not for Tantalum. No. 6994, 1985, p. 15.

[7] Industrial Minerals (London). Lithium Reserves and the Chilean Factor. No. 215, 1985, p. 19.

[8] Mining Journal (London). SCL Lithium Expansion Plans. V. 305, No. 7825, 1985, p. 103.

[9] Metal Bulletin (London). Pechiney Lithium Finance Agreed. No. 7033, 1985, p. 15.

[10] Lithium Corp. of America. News Release. Gastonia, NC, Sept. 11, 1985.

[11] Metals Week. Lithco Expanding Capacity in Europe. V. 56, No. 14, 1985, p. 6.

[12] Metal Bulletin (London). Lithium Alloys Take to the Air. No. 6988, 1985, p. 19.

## Table 5.—Lithium minerals and brine: World production, by country[1]

(Short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina (minerals not specified) | 28 | 125 | 168 | 24 | 22 |
| Australia, spodumene[3] | -- | [e]90 | 1,100 | 7,200 | [4]12,300 |
| Brazil: | | | | | |
| Amblygonite | 305 | 73 | 125 | 54 | 83 |
| Lepidolite | 2 | 82 | 1 | ([5]) | -- |
| Petalite | 2,293 | 2,528 | 2,086 | 526 | 550 |
| Spodumene | 268 | 376 | 128 | 817 | 330 |
| Canada, spodumene[e] [6] | -- | -- | -- | 90 | 1,200 |
| Chile (carbonate from subsurface brine) | -- | -- | -- | 2,326 | [4]4,969 |
| China (minerals not specified)[e] [7] | 15,400 | 15,400 | 16,500 | 16,500 | 16,500 |
| Namibia (minerals not specified) | 1,392 | 1,146 | 860 | 970 | 2,160 |
| Portugal, lepidolite | 990 | [r]998 | 601 | [e]660 | 720 |
| Rwanda, amblygonite[e] | ([5]) | -- | -- | -- | -- |
| U.S.S.R. (minerals not specified)[e] [7] | 60,600 | 60,600 | 60,600 | 60,600 | 60,600 |
| United States, spodumene and subsurface brine | W | W | W | W | W |
| Zimbabwe (minerals not specified) | 18,126 | 10,788 | 21,157 | 25,270 | 27,700 |

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data.

[1] Table includes data available through May 20,1986.

[2] In addition to the countries listed, other nations may produce small quantities of lithium minerals, but output is not reported and no valid basis is available for estimating production levels.

[3] Data are for years ending June 30 of that stated.

[4] Reported figure.

[5] Revised to zero.

[6] Estimates from U.S. imports from Canada.

[7] These estimates denote only an approximate order of magnitude; no basis for more exact estimates is available. Output by China and the U.S.S.R. has never been reported.

# Magnesium

### By Deborah A. Kramer[1]

Both domestic production and consumption of primary magnesium in 1985 decreased from those of 1984, owing principally to a decline in demand for magnesium for aluminum alloying. Magnesium alloy manufacturers continued to introduce high-purity versions of conventional alloys, which led to an increased demand for magnesium in structural applications in the automotive and aerospace industries. The United States remained a net exporter of magnesium, although both exports and imports of magnesium materials declined.

**Domestic Data Coverage.**—Domestic consumption data for magnesium metal are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the 159 operations to which a survey request was sent, 82% responded, representing 88% of the primary magnesium consumption shown in tables 1 and 3. Consumption for the 28 nonrespondents was estimated using reported prior year consumption levels.

**Table 1.—Salient magnesium statistics**

(Short tons unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production: | | | | | |
| Primary magnesium | 153,782 | 102,197 | 115,481 | 159,207 | 149,614 |
| Secondary magnesium | 46,256 | 43,232 | 46,329 | r48,357 | 45,523 |
| Exports | 34,855 | 39,613 | 46,690 | 48,337 | 40,322 |
| Imports for consumption | 6,897 | 4,784 | 6,350 | 9,381 | 9,271 |
| Consumption, primary | 91,461 | 74,599 | 81,976 | r89,887 | 83,502 |
| Price per pound | $1.25-$1.34 | $1.34 | $1.38 | $1.43-$1.48 | $1.48-$1.53 |
| World: Primary production | r339,731 | r279,568 | 286,204 | p360,236 | e360,504 |

eEstimated. pPreliminary. rRevised.

**Legislation and Government Programs.**—The Environmental Protection Agency issued final regulations under the Clean Water Act for specified nonferrous metals forming operations. These regulations limit the discharge of pollutants by existing and new operations into navigable waters and into publicly owned water treatment works. Effluent discharges from magnesium operations were to be regulated for ammonia, chromium, fluoride, and zinc contaminants. Daily and monthly effluent limits for these contaminants varied according to type of operation and effluent source.[2]

## DOMESTIC PRODUCTION

Primary magnesium production was about 80% of annual capacity. Three companies produced primary magnesium metal: AMAX Magnesium Corp., Rowley, UT; The Dow Chemical Co., Freeport, TX; and Northwest Alloys Inc., a subsidiary of Aluminum Co. of America, Addy, WA. AMAX and Dow produced magnesium from natural brines by the electrolytic process, and Northwest Alloys produced metal from dolomite using the silicothermic process.

Dow announced plans to spend $40 million to modernize its magnesium and aluminum production facilities over the next 3 years. Although the modernization at Dow's Freeport plant will not increase production capacity, the company intended to improve energy efficiency, labor productivity, raw material yields, and product quality through the use of new production and foundry technology.

Interstrat Resources Inc., a Vancouver, Canada-based firm, obtained financing to begin a feasibility study on its Pine Flat Mountain magnesium-nickel-cobalt-chromium property on the California-Oregon border. The feasibility study was to be conducted by Davy McKee Corp. and was expected to concentrate on the following areas: geology and geostatistical analysis, mining, process development, engineering, and environmental impact. Reserves at the Pine Flat Mountain laterite deposit were estimated to be over 25 million short tons grading 24.5% magnesium oxide, 0.78% nickel, 0.61% cobalt, and 1.13% chromium. Davy McKee prepared a preliminary evaluation, which indicated that a 4,000-ton-per-day processing complex could produce 80,000 tons of magnesium metal, 12,000 tons of nickel, 1,000 tons of cobalt, and 20,000 tons of chromium annually, for a minimum 10-year mine life. The study stated that such a plant would cost $230 million.

### Table 2.—Magnesium recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| KIND OF SCRAP | | | | | |
| New scrap: | | | | | |
| Magnesium-base | 2,833 | 2,455 | 2,878 | [r]3,192 | 1,664 |
| Aluminum-base | 19,240 | 17,346 | 18,718 | [r]18,402 | 17,915 |
| Total | 22,073 | 19,801 | 21,591 | [r]21,594 | 19,579 |
| Old scrap: | | | | | |
| Magnesium-base | 5,593 | 5,314 | 5,311 | [r]5,232 | 5,104 |
| Aluminum-base | 18,590 | 18,117 | 19,427 | 21,531 | 20,840 |
| Total | 24,183 | 23,431 | 24,738 | [r]26,763 | 25,944 |
| Grand total | 46,256 | 43,232 | 46,329 | [r]48,357 | 45,523 |
| FORM OF RECOVERY | | | | | |
| Magnesium alloy ingot[1] | 4,230 | 4,228 | 4,232 | [r]4,229 | 4,231 |
| Magnesium alloy castings (gross weight) | 806 | 746 | 952 | [r]980 | 483 |
| Magnesium alloy shapes | 13 | -- | -- | -- | -- |
| Aluminum alloys | 38,755 | 36,587 | 39,451 | [r]41,072 | 39,459 |
| Zinc and other alloys | 9 | 11 | 20 | [r]12 | 9 |
| Chemical and other dissipative uses | 55 | 3 | 4 | [r]9 | 3 |
| Cathodic protection | 2,388 | 1,657 | 1,670 | [r]2,055 | 1,338 |
| Total | 46,256 | 43,232 | 46,329 | [r]48,357 | 45,523 |

[r] Revised.

[1] Includes secondary magnesium content of both secondary and primary alloy ingot.

## CONSUMPTION AND USES

Primary magnesium consumption declined from that of 1984, chiefly owing to a decrease in consumption for the major end use, aluminum alloying. Although total demand decreased, magnesium consumption for structural uses, principally diecasting and extrusions, and as a reducing agent for titanium increased significantly. Primary magnesium demand for iron and steel desulfurization was estimated to be 8,000 tons.

Automobile manufacturers continued to replace some aluminum parts with magnesium components. Ford Motor Co. announced that it intended to use die-cast magnesium transfer case housings for its 1987 model year F-Series pickup trucks and full-size Bronco vehicles. The transfer cases, weighing about 14 pounds, will replace 21-pound aluminum transfer cases and were expected to increase domestic magnesium consumption by 2 to 2.5 million pounds per year. Magnesium clutch housings, similar to those used in the 1984 models of Ford's Ranger II and Bronco trucks, were expected to be installed in Ford's compact-size Aerostar vans.

Photoengraving Inc. reportedly substituted magnesium for zinc on its steel-backed dry offset printing plates used in printing preformed packaging. Advantages of the magnesium plate include sharper printed image, longer plate life, reduced cost of etching solution, and faster etching time.[8]

Tracor MBA, a subsidiary of Tracor Inc., reportedly began production of atomized magnesium powder at its Camden, AR, plant. Initially, the company planned to use the powder in production of infrared flares, but expected to market the powder when production reached 500 pounds per day.

Oregon Metallurgical Corp. installed four additional electrolytic cells at its Albany, OR, facility to recover magnesium from magnesium chloride generated during titanium sponge production at a cost of $1.8 million. Space was provided for an additional eight cells. The 4 completed cells increased the company's total to 25, with a recovery capacity of 3,500 tons of magnesium per year.

Increased demand for magnesium was the reason for Dow's decision to add a third extrusion press and expand its manufacturing facility at Aurora, CO. The expansion reportedly will increase Dow's extruding capacity by nearly one-third.

### Table 3.—U.S. consumption of primary magnesium, by use

(Short tons)

| Use | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| For structural products: | | | | | |
| Castings: | | | | | |
| Die | 2,812 | 1,600 | 1,937 | [r]595 | 2,457 |
| Permanent mold | 917 | 663 | 16 | 1,666 | 909 |
| Sand | 1,222 | 1,337 | 1,388 | 1,932 | 1,634 |
| Wrought products: | | | | | |
| Extrusions | 5,786 | 7,059 | 7,093 | 5,828 | 7,756 |
| Sheet and plate | 4,547 | 2,981 | 4,813 | [r]4,378 | 4,182 |
| Other (includes forgings) | 48 | 88 | 29 | 40 | 11 |
| Total | 15,327 | 13,728 | 14,776 | [r]14,439 | 16,949 |
| For distributive or sacrificial purposes: | | | | | |
| Alloys: | | | | | |
| Aluminum | 50,518 | 39,878 | 46,026 | [r]48,673 | 40,850 |
| Copper | 5 | 7 | 4 | 4 | 4 |
| Zinc | 9 | 3 | 3 | [r]4 | 3 |
| Other | 7 | 3 | -- | -- | 1 |
| Cathodic protection (anodes) | 6,449 | 5,964 | 5,686 | [r]4,777 | 4,748 |
| Chemicals | 5,315 | 4,823 | 5,664 | [r]5,501 | 3,824 |
| Nodular iron | 3,755 | 2,541 | 2,200 | [r]2,408 | 1,698 |
| Reducing agent for titanium, zirconium, hafnium, uranium, beryllium | 9,071 | 5,901 | 4,711 | 6,689 | 8,126 |
| Other[1] | 1,005 | 1,751 | 2,906 | 7,392 | 7,299 |
| Total | 76,134 | 60,871 | 67,200 | [r]75,448 | 66,553 |
| Grand total | 91,461 | 74,599 | 81,976 | [r]89,887 | 83,502 |

[r] Revised.
[1] Includes scavenger, deoxidiser, and powder.

## STOCKS

Consumer stocks of primary magnesium ingot declined from 6,920 tons (revised) at yearend 1984 to 6,168 tons at yearend 1985. Stocks of magnesium alloy ingot decreased from 585 tons (revised) at yearend 1984 to 428 tons at yearend 1985. Primary producer stocks of magnesium rose from 27,116 tons at yearend 1984 to 36,736 tons at yearend 1985.

**Table 4.—Stocks and consumption of new and old magnesium scrap in the United States**

(Short tons)

| | Stocks, Jan. 1 | Receipts | Consumption: New scrap | Consumption: Old scrap | Consumption: Total | Stocks, Dec. 31 |
|---|---|---|---|---|---|---|
| 1984:[r] | | | | | | |
| Cast scrap | 1,222 | 5,597 | 363 | 5,232 | 5,595 | 1,224 |
| Solid wrought scrap[1] | 41 | 694 | 694 | -- | 694 | 41 |
| Total | 1,263 | 6,291 | 1,057 | 5,232 | 6,289 | 1,265 |
| 1985: | | | | | | |
| Cast scrap | 1,224 | 5,078 | 15 | 5,104 | 5,119 | 1,183 |
| Solid wrought scrap[1] | 41 | 430 | 439 | -- | 439 | 32 |
| Total | 1,265 | 5,508 | 454 | 5,104 | 5,558 | 1,215 |

[r] Revised.

[1] Includes borings, turnings, drosses, etc.

## PRICES

At the beginning of the year, the price for primary magnesium ingot was quoted by Dow and AMAX at $1.48 per pound and remained at that level until early December. At that time, Dow announced an increase of its price to $1.53 per pound, effective December 9 for noncontract customers and as terms permit for contract customers. AMAX also announced that it would increase its primary ingot price to match Dow's, effective January 1, 1986. At yearend, the quoted price for primary magnesium ingot was $1.48 to $1.53 per pound.

Diecasting alloy producer prices were quoted at $1.26 to $1.30 per pound at the beginning of 1985. Along with price increases for primary ingot, Dow increased its price for diecasting alloy from $1.30 to $1.40, effective December 9, and AMAX increased its price from $1.26 to $1.29, effective January 1, 1986. Dow later announced a price reduction to $1.33 effective January 20. At yearend, the prices quoted by the producers for diecasting alloy were $1.26 to $1.40. Both companies cited increased production costs as the reason for the price hikes. These were the first price increases announced since July 1984.

## FOREIGN TRADE

Exports of magnesium declined 17% in both quantity and value from those of 1984. Japan and the Netherlands continued to be the primary destinations, together accounting for 55% of U.S. exports. The United States remained a net exporter of magnesium.

Magnesium imports in 1985 decreased slightly from those of 1984, both in quantity and value. Canada and Norway were the primary import sources, together accounting for 54% of the total.

## Table 5.—U.S. exports and imports for consumption of magnesium

| Year | EXPORTS | | | | | |
|---|---|---|---|---|---|---|
| | Waste and scrap | | Metals and alloys in crude form | | Semifabricated forms, n.e.c. | |
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1983 | 638 | $1,681 | 43,992 | $111,988 | 2,060 | $11,045 |
| 1984 | 1,249 | 3,362 | 44,880 | 120,804 | 2,208 | 12,495 |
| 1985 | 795 | 2,071 | 37,484 | 100,123 | 2,043 | 11,401 |

| Year | IMPORTS FOR CONSUMPTION | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Waste and scrap | | Metal | | Alloys (magnesium content) | | Powder, sheets, tubing, ribbons, wire, other forms (magnesium content) | |
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1983 | 1,985 | $2,537 | 2,034 | $4,637 | 2,143 | $6,151 | 288 | $2,939 |
| 1984 | 2,160 | 3,656 | 3,136 | 8,604 | 3,596 | 10,791 | 489 | 2,620 |
| 1985 | 2,874 | 4,778 | 1,992 | 5,525 | 3,651 | 12,774 | 754 | 2,010 |

Source: Bureau of the Census.

## Table 6.—U.S. exports of magnesium, by country

| Country | Waste and scrap | | Primary metals, alloys | | Semifabricated forms, n.e.c., including powder | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1984 | | | | | | |
| Argentina | -- | -- | 580 | $1,498 | 23 | $101 |
| Australia | -- | -- | 2,045 | 5,246 | 227 | 1,095 |
| Austria | -- | -- | 404 | 1,170 | 13 | 259 |
| Belgium-Luxembourg | -- | -- | -- | -- | 17 | 169 |
| Brazil | -- | -- | 344 | 908 | 3 | 18 |
| Canada | 688 | $1,578 | 4,910 | 13,328 | 595 | 2,043 |
| China | -- | -- | 1,390 | 3,887 | -- | -- |
| Colombia | -- | -- | 59 | 166 | 3 | 17 |
| Egypt | -- | -- | -- | -- | 10 | 31 |
| France | (1) | 2 | (1) | 1 | 49 | 859 |
| Germany, Federal Republic of | 225 | 559 | 469 | 1,557 | 30 | 338 |
| India | -- | -- | 109 | 307 | 11 | 49 |
| Israel | -- | -- | 2 | 11 | 57 | 328 |
| Italy | -- | -- | 26 | 78 | 107 | 1,013 |
| Japan | 59 | 10 | 12,042 | 28,856 | 106 | 802 |
| Korea, Republic of | 38 | 113 | 297 | 821 | 1 | 22 |
| Mexico | 90 | 232 | 2,920 | 7,541 | 132 | 609 |
| Netherlands | 30 | 62 | 17,759 | 50,707 | 481 | 1,624 |
| New Zealand | -- | -- | 54 | 130 | 1 | 23 |
| Norway | -- | -- | 48 | 769 | 4 | 59 |
| Saudi Arabia | -- | -- | 1 | 3 | 10 | 22 |
| Singapore | 94 | 765 | 33 | 142 | 10 | 30 |
| South Africa, Republic of | -- | -- | 612 | 1,694 | 45 | 277 |
| Spain | -- | -- | -- | -- | 31 | 337 |
| Sweden | -- | -- | 3 | 7 | 36 | 288 |
| Taiwan | 22 | 21 | 122 | 375 | 11 | 54 |
| United Kingdom | (1) | 13 | 139 | 420 | 144 | 1,541 |
| Venezuela | -- | -- | 326 | 589 | 1 | 11 |
| Other | 3 | 7 | 186 | 598 | r50 | r476 |
| Total | 1,249 | 3,362 | 44,880 | 120,804 | 2,208 | 12,495 |

See footnotes at end of table.

### Table 6.—U.S. exports of magnesium, by country —Continued

| Country | Waste and scrap | | Primary metals, alloys | | Semifabricated forms, n.e.c., including powder | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| **1985** | | | | | | |
| Argentina | -- | -- | 240 | $634 | 8 | $43 |
| Australia | -- | -- | 1,710 | 3,960 | 269 | 1,438 |
| Austria | -- | -- | 308 | 916 | 6 | 78 |
| Belgium-Luxembourg | -- | -- | 53 | 157 | 15 | 93 |
| Brazil | -- | -- | 131 | 326 | 2 | 19 |
| Canada | 377 | $875 | 4,880 | 12,805 | 684 | 2,462 |
| China | -- | -- | 3,132 | 8,326 | -- | -- |
| Colombia | -- | -- | 24 | 63 | 37 | 98 |
| Egypt | -- | -- | 336 | 1,048 | 2 | 4 |
| France | 1 | 2 | -- | -- | 17 | 414 |
| Germany, Federal Republic of | 325 | 1,005 | 139 | 442 | 29 | 334 |
| India | -- | -- | 505 | 1,382 | 3 | 20 |
| Israel | -- | -- | 5 | 34 | 44 | 221 |
| Italy | -- | -- | 3 | 16 | 33 | 739 |
| Japan | 9 | 8 | 11,149 | 28,602 | 177 | 1,017 |
| Korea, Republic of | -- | -- | 354 | 1,054 | 91 | 396 |
| Mexico | 19 | 45 | 2,462 | 6,350 | 162 | 878 |
| Netherlands | -- | -- | 10,773 | 30,609 | 39 | 212 |
| New Zealand | -- | -- | 36 | 87 | 1 | 21 |
| Norway | -- | -- | 109 | 293 | 6 | 68 |
| Saudi Arabia | -- | -- | 7 | 30 | 23 | 59 |
| Singapore | -- | -- | 2 | 3 | 30 | 63 |
| South Africa, Republic of | -- | -- | 429 | 1,219 | 37 | 156 |
| Spain | -- | -- | 21 | 10 | 14 | 213 |
| Sweden | -- | -- | 6 | 15 | 12 | 172 |
| Taiwan | -- | -- | 225 | 664 | 19 | 43 |
| United Kingdom | 64 | 136 | 11 | 65 | 141 | 1,523 |
| Venezuela | -- | -- | 127 | 333 | 1 | 15 |
| Other | -- | -- | 257 | 685 | 91 | 607 |
| Total | 795 | 2,071 | 37,434 | 100,128 | 2,043 | 11,401 |

[r] Revised.
[1] Less than 1/2 unit.

Source: Bureau of the Census.

### Table 7.—U.S. import duties for magnesium

| Item | TSUS No. | Most favored nation (MFN) | | Non-MFN |
|---|---|---|---|---|
| | | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Unwrought metal | 623.55 | 12% ad valorem | 8% ad valorem | 100% ad valorem. |
| Unwrought alloys | 623.57 | 6.7% ad valorem | 6.5% ad valorem | 60.5% ad valorem. |
| Wrought metal | 623.59 | 5 cents per pound on magnesium content plus 2.8% ad valorem. | 4.5 cents per pound on magnesium content plus 2.5% ad valorem. | 40 cents per pound on magnesium content plus 20% ad valorem. |

## WORLD REVIEW

**Canada.**—Norsk Hydro A/S, based in Norway, planned to construct a 55,000-ton-per-year primary magnesium plant in Bécancour, Quebec, at a cost of $220 million. The company reportedly awarded a contract for the feasibility study on plant construction, and construction was expected to begin in the first half of 1989. Norsk initially expected to use imported magnesium oxide as a raw material for the process, but planned to develop raw material production in Quebec in the future. Norsk planned to market the magnesium in the United States and chose Canada rather than the United States for the plantsite because of lower energy prices. The location in Canada also would reduce the company's shipping costs of exporting magnesium to the United States from Norway.[4]

Webster Manufacturing Ltd., a wholly owned subsidiary of CAE Industries Ltd., was awarded a long-term $70 million contract by General Motors Corp. (GM) to manufacture die-cast magnesium steering column brackets for the new GM W-body car. Construction of a new facility in Strathroy, Ontario, to house new diecasting machines, a tool-and-die shop, and a machine shop was expected to begin late in the year.

**China.**—The China National Nonferrous Metals Industry Corp. reportedly planned to import magnesium technology and equipment to modernize its primary magnesium plant in Qinghai Province. Most of the magnesium in China is used for titanium production.

**India.**—Tamil Nadu Chemical Products Corp. of Madras reportedly planned to construct a primary magnesium plant with a 600-ton-per-year capacity in Valinokkam, Ramanathapuram District. Because India's annual magnesium demand of about 1,500 to 2,000 tons was met almost exclusively from imports, domestic production of the metal was expected to reduce costs. Construction of the new plant, which would be the first in the world to use sea bitterns as a raw material, was expected to begin in late 1987.

**Japan.**—Primary magnesium demand in Japan was almost 24,000 tons in 1985, an increase of 4% from that of 1984. Imports of over 17,000 tons supplied most of this demand, with 72% of the imports received from the United States and 20% from Norway. Exports from Japan were about 2,800 tons, and 75% of this material was exported to the U.S.S.R. Over one-half of the magnesium demand in Japan was for rolled products.[8]

### Table 8.—Magnesium: World primary production, by country[1]

(Short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Brazil | -- | -- | -- | 1,100 | 2,200 |
| Canada[e] | [2]9,870 | 8,700 | 6,600 | 8,800 | 7,700 |
| China[e] | 7,700 | 7,700 | 7,700 | 7,700 | 7,700 |
| France | 8,006 | 10,598 | 12,208 | 14,299 | 14,300 |
| Italy | [r]11,900 | [r]10,960 | 8,478 | 8,257 | [2]8,667 |
| Japan | 6,247 | 6,123 | 6,643 | 7,830 | [2]9,323 |
| Norway | 52,472 | 89,598 | 82,897 | 54,343 | 60,000 |
| U.S.S.R.[e] | 86,000 | 89,000 | 91,000 | 94,000 | [illegible] |
| United States | 153,782 | 102,197 | 115,481 | 159,207 | [2]148,614 |
| Yugoslavia | 4,254 | 4,697 | 5,252 | [e]4,700 | 5,000 |
| Total | [r]339,731 | [r]279,568 | 286,204 | 360,236 | 360,504 |

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Table includes data available through June 3, 1986.
[2]Reported figure.

### Table 9.—Magnesium: World secondary production, by country[1]

(Short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Japan | 31,345 | 23,887 | 14,343 | 17,258 | 23,000 |
| U.S.S.R.[e] | 9,000 | 9,000 | 9,000 | 9,000 | 9,000 |
| United Kingdom | 2,100 | 1,940 | [r] [e]1,900 | ([2]) | NA |
| United States | 46,256 | 43,232 | 46,329 | [r] 48,357 | [3]45,523 |
| Total | 88,701 | 78,059 | 71,572 | 74,615 | 77,523 |

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.
[1]Table includes data available through June 3, 1986.
[2]Revised to not available.
[3]Reported figure.

## TECHNOLOGY

Scientists at Dow developed wear-resistant prototype components, primarily for the automotive industry, manufactured from a magnesium-alumina composite material. Because of their poor wear resistance, magnesium alloys generally are not used in applications where two surfaces rub together. By a proprietary mixing technique, 1% to 10% alumina, by weight, was added to molten AZ91 magnesium alloy, and the resulting composite was cast using standard techniques for die or permanent mold castings. The added alumina provides wear resistance and does not increase the weight of the casting significantly. Several components, including an oil pump and camshaft cover and a cog-tooth timing belt pulley, reportedly were developed and were tested under actual operating conditions.[6]

Dow introduced a high-purity version of its diecasting alloy, AM60, that was used in some automotive wheels and in archery bows and fishing rod handles. Dow maintained that the high-purity alloy, which minimizes contaminants such as copper, iron, and nickel, has corrosion resistance that is equal to or better than comparable aluminum alloys. High-purity AM60 reportedly has better elongation and impact properties than other diecasting compositions, and it increases Dow's line of high-purity alloys, including AZ91D, a diecasting alloy, and AZ91C/HP, a sand-casting alloy.

Researchers at Magnesium Elektron Ltd. in the United Kingdom reportedly developed a new casting alloy WE54 primarily for applications in the aerospace industry. The new alloy, which was designed to improve temperature stability and elevated temperature properties of conventional magnesium alloys, was composed of magnesium, yttrium, neodymium, and zirconium. Special melting techniques were devised for this alloy, because it could not be melted using conventional fluxes without high yttrium losses. Possible applications for WE54 include components for airframes, engines, flight equipment, weapons, and high-performance automobiles.[7]

A die-cast magnesium insert permitted driving a military vehicle up to 30 miles at 30 miles per hour with two of its four tires deflated. The insert was developed for the U.S. Army's aluminum body, 1-1/4-ton, 4-by-4 high-mobility multipurpose wheeled vehicle (Hummer), and it resembles an additional wheel within the tire and is mounted on the rim. Over the next 5 years, 55,000 Hummers were scheduled to be built, and all were expected to be equipped with the insert.[8]

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[1] Physical scientist, Division of Nonferrous Metals.

[2] Federal Register. Nonferrous Metals Forming and Metal Powders Point Source Category; Copper Forming Point Source Category; Effluent Limitations Guidelines; Pretreatment Standards, and New Source Performance Standards. V. 50, No. 164, Aug. 23, 1985, pp. 34242-34334.

[3] Pennington, N. Magnesium Structural Uses Show New Growth Potential. Mod. Met., v. 41, No. 1, Feb. 1985, pp. 51-64.

[4] Kolrud, J. Norsk Hydro Looks To Expand Into North America. Met. Bull. Mon. (London), No. 180, Dec. 1985, p. 69.

[5] Japan Metal Journal. V. 16, No. 13, Mar. 13, 1986, p. 9.

[6] Shook, S. Prototype Evaluation of Reinforced Magnesium Composite Parts. Paper in Proc. 42d Annual World Magnesium Conference, New York, NY (May 19-21, 1985). Int. Magnesium Assoc., Dayton, OH, 1985, pp. 19-25.

[7] Unsworth B., and J. King. Foundry Alloys Evolve To Meet Aerospace Demands. Met. Bull. Mon. (London), No. 180, Dec. 1985, pp. 74-77.

[8] Work cited in footnote 3.

# Magnesium Compounds

## By Deborah A. Kramer[1]

Magnesium compounds shipped or used by producers in 1985 declined dramatically from those of 1984. Shipments of caustic-calcined magnesia declined to their lowest level in 20 years, and refractory magnesia shipments reached their lowest level in more than 40 years. Over the past 3 years, imported material supplied an increasingly greater share of the domestic magnesium compound demand. The increased reliance on imports was due, in part, to the strength of the U.S. dollar.

Natural brines continued to be the dominant source of domestically produced magnesium compounds. Magnesium oxide and other compounds were produced from seawater by five companies in California, Delaware, Florida, and Texas; from well brines by three companies in Michigan; and from lake brines by two companies in Utah. Magnesite was mined by one company in Nevada, and olivine was mined by two companies in North Carolina and Washington.

**Domestic Data Coverage.**—Domestic data for magnesium compounds shipped and used are developed by the Bureau of Mines from a voluntary survey of U.S. operations entitled "Magnesium Compounds." Of the 18 operations to which a survey request was sent, 83% responded, representing 59% of the total magnesium compounds shipped and used shown in table 3. Data for the three nonrespondents were estimated using prior year production levels and other factors.

Table 1.—Salient magnesium compound statistics

(Thousand short tons and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Caustic-calcined and specified magnesias:[1] | | | | | |
| Shipped by producers:[2] | | | | | |
| Quantity | 160 | 148 | 143 | [r]142 | 100 |
| Value | $58,420 | $56,368 | $57,416 | [r]$42,257 | $33,772 |
| Exports: Value[3] | $14,559 | $10,925 | $8,426 | $14,026 | $9,773 |
| Imports for consumption: Value[3] | $2,177 | $2,055 | $5,476 | $9,594 | $10,407 |
| Refractory magnesia: | | | | | |
| Shipped by producers:[2] | | | | | |
| Quantity | 616 | 453 | 456 | 374 | 290 |
| Value | $146,903 | $112,101 | $98,478 | $87,945 | $81,149 |
| Exports: Value | $4,727 | $2,721 | $1,955 | $3,641 | $5,529 |
| Imports for consumption: Value | $22,990 | $14,162 | $11,495 | [r]$23,715 | $29,767 |
| Dead-burned dolomite: | | | | | |
| Sold and used by producers: | | | | | |
| Quantity | 435 | 337 | 418 | 487 | [p]411 |
| Value | $23,789 | $19,136 | $24,454 | $29,891 | [p]$24,804 |
| World: Production (magnesite) | [r]12,478 | [r]12,554 | 12,253 | [p]13,121 | [e]13,208 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Excludes caustic-calcined magnesia used in the production of refractory magnesia.

[2] Includes magnesia used by producers:

[3] Caustic-calcined magnesia only.

## DOMESTIC PRODUCTION

Seawater and well and lake brines continued to be the primary source of domestically produced magnesium compounds. Magnesium compounds also were recovered from magnesite and dolomite.

As part of a restructuring plan, Kaiser Aluminum & Chemical Corp. sold its refractories division, including its seawater plant at Moss Landing, CA, to a group of the company's employees. A new company was reorganized under the name National Refractories & Minerals Corp. to operate the plant.

Olivine was mined from deposits in North Carolina and Washington. Shipments declined significantly to about one-half those of 1984. Olivine was ground to various grades for consumption by the foundry, refractory, and steel industries.

National Olivine Corp., Dillsboro, NC, filed for bankruptcy late in 1984, and all the company's equipment and property was sold in May 1985. The State was suing for enough money to finance the property reclamation, which was estimated to cost at least $75,000. National Olivine had property leases in the Buck Creek area, which reverted to Appalachian Resources Inc.

Table 2.—Magnesium compound producers, by raw material source, location, and production capacity in 1985

| Raw material source and producing company | Location | Capacity (short tons of MgO equivalent) |
|---|---|---|
| Magnesite: Basic Inc | Gabbs, NV | 150,000 |
| Lake brines: | | |
| Great Salt Lake Minerals & Chemicals Corp | Ogden, UT | 100,000 |
| Kaiser Aluminum & Chemical Corp | Wendover, UT | 50,000 |
| Well brines: | | |
| The Dow Chemical Co | Ludington, MI | 300,000 |
| Do | Midland, MI | 75,000 |
| Martin Marietta Chemicals | Manistee, MI | 350,000 |
| Morton Chemical Co | do | 5,000 |
| Seawater: | | |
| Barcroft Co | Lewes, DE | 5,000 |
| Basic Magnesia Inc | Port St. Joe, FL | 100,000 |
| The Dow Chemical Co | Freeport, TX | 75,000 |
| Merck & Co. Inc | South San Francisco, CA | 15,000 |
| National Refractories & Minerals Corp | Moss Landing, CA | 150,000 |
| Total | | 1,375,000 |

## CONSUMPTION AND USES

Most of the domestic magnesium compound production was used in the manufacture of refractory products such as refractory brick. Magnesia and magnesia-based bricks were used primarily by the iron and steel industry for furnace linings. Demand for refractory magnesia fell moderately during the past 3 years; however, total shipments of refractory magnesia decreased rapidly and in 1985 were less than 64% of those of 1982. Consequently, domestic demand was met, in part, by an increase in imports over the past 3 years.

Total shipments of caustic-calcined and specified magnesias decreased to about 70% of those of 1984. These compounds were used in diverse industries including agriculture, chemical processing, and construction. Animal feed, accounting for 36% of the total shipments of caustic-calcined magnesia, was the largest consuming industry in 1985. Representing 31% of the total domestic shipments of caustic-calcined magnesia were, in declining order, the sectors of ceramics, petroleum additives, stack-gas scrubbing, and rayon. The following uses, in declining order, accounted for the remaining 33% of the total shipments: rubber, refractories, chemical, oxychloride and oxysulfate cements, electrical heating rods, insulation and wallboard, water treatment, sugar and candy, medicine and pharmaceuticals, fertilizer, foundry, uranium processing, and pulp and paper.

### Table 3.—U.S. magnesium compounds shipped and used

| | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Caustic-calcined[1] and specified (USP and technical) magnesias | [r]141,634 | [r]$42,257 | 99,517 | $33,772 |
| Magnesium hydroxide (100% Mg(OH)$_2$)[1] | [r]356,985 | [r]41,400 | 263,712 | 68,975 |
| Magnesium sulfate (anhydrous and hydrous) | 49,776 | 13,214 | 55,863 | 14,813 |
| Precipitated magnesium carbonate[1] | [r]5,194 | [r]875 | 3,746 | 702 |
| Refractory magnesia | 374,280 | 87,945 | 290,271 | 81,149 |

[r] Revised.

[1] Excludes material produced as an intermediate step in the manufacture of other magnesium compounds.

## PRICES

Yearend prices for magnesium compounds, published in the Chemical Marketing Reporter, did not change from those published at yearend 1984. Prices for magnesium compounds at yearend 1985 were as follows: magnesia, natural, technical, heavy, 85% and 90% (f.o.b. Nevada), $232 and $265 per short ton, respectively; magnesium chloride, hydrous, 99%, flake, $290 per ton; magnesium carbonate, light, technical (freight equalized), $0.73 to $0.83 per pound; magnesium hydroxide, National Formulary (NF), powder (freight equalized), $0.78 per pound; and magnesium sulfate, technical, $0.115 per pound.

## FOREIGN TRADE

Exports of crude and processed magnesite decreased slightly in quantity from those of 1984. Canada remained the primary destination, but its share of the U.S. export market for magnesium compounds declined dramatically from 76% in 1984 to 53% in 1985.

### Table 4.—U.S. exports of magnesite and magnesia, by country

| Country | Magnesite and magnesia, dead-burned | | | | Magnesite, n.e.c., including crude caustic-calcined, lump or ground | | | |
|---|---|---|---|---|---|---|---|---|
| | 1984 | | 1985 | | 1984 | | 1985 | |
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Argentina | -- | -- | -- | -- | 562 | $180 | 54 | $48 |
| Australia | -- | -- | -- | -- | 135 | 186 | 469 | 260 |
| Belgium-Luxembourg | -- | -- | -- | -- | 444 | 448 | 414 | 310 |
| Brazil | -- | -- | -- | -- | 42 | 97 | 58 | 165 |
| Canada | 14,439 | $3,273 | 16,391 | $3,704 | 23,115 | 8,032 | 8,277 | 3,191 |
| Colombia | 1,208 | 147 | 1,511 | 216 | 129 | 155 | 72 | 101 |
| France | -- | -- | -- | -- | 220 | 174 | 5,761 | 1,800 |
| Germany, Federal Republic of | -- | -- | -- | -- | 544 | 423 | 447 | 351 |
| Israel | -- | -- | -- | -- | 1,132 | 789 | 973 | 505 |
| Italy | -- | -- | -- | -- | 315 | 349 | 137 | 124 |
| Korea, Republic of | -- | -- | -- | -- | 325 | 233 | 249 | 182 |
| Mexico | -- | -- | 6 | 1 | 1,047 | 398 | 804 | 545 |
| Netherlands | -- | -- | -- | -- | 663 | [r]507 | 557 | 472 |
| New Zealand | -- | -- | 172 | 82 | 88 | [r]131 | 30 | 45 |
| Saudi Arabia | 327 | 62 | 2,872 | 525 | -- | -- | -- | -- |
| Spain | -- | -- | -- | -- | 227 | 235 | 107 | 68 |
| Sweden | 809 | 83 | -- | -- | 197 | 145 | 270 | 188 |
| Taiwan | 22 | 3 | 38 | 5 | 3 | 121 | 172 | 104 |
| United Kingdom | -- | -- | -- | -- | 133 | 180 | 125 | 193 |
| Venezuela | -- | -- | 3,306 | 893 | 2,265 | 999 | 2,444 | 895 |
| Other | [r]470 | [r]73 | 509 | 103 | [r]467 | [r]244 | 147 | 226 |
| Total | 17,275 | 3,641 | 24,805 | 5,529 | 32,053 | 14,026 | 21,567 | 9,773 |

[r] Revised.

Source: Bureau of the Census.

Total imports of crude and processed magnesite were at their highest level in more than 30 years, increasing more than 15% over those of 1984. For caustic-calcined magnesia, Canada remained the largest import source, accounting for about 62% of the total quantity. Four countries, China, Greece, Ireland, and the United Kingdom, accounted for about 74% of the total quantity of U.S. imports of dead-burned magnesia. In addition, other magnesium compounds valued at more than $10 million were imported.

### Table 5.—U.S. import duties for magnesium compounds

| Item | TSUS No. | Most favored nation (MFN) |  | Non-MFN |
|---|---|---|---|---|
|  |  | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Crude magnesite | 522.61 | 65 cents per ton | Free | $10.50 per ton. |
| Caustic-calcined magnesite | 522.64 | $2.10 per ton | $2.10 per ton | $21.00 per ton. |
| Refractory magnesia (containing not over 4% lime). | 531.01 | 0.17 cent per pound. | 0.16 cent per pound. | 0.75 cent per pound. |
| Refractory magnesia (containing over 4% lime). | 531.04 | 6% ad valorem | 6% ad valorem | 30% ad valorem. |

### Table 6.—U.S. imports for consumption of crude and processed magnesite, by country

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Lump or ground caustic-calcined magnesia:[1] |  |  |  |  |
| Australia | -- | -- | 296 | 352 |
| Canada | r30,126 | $5,961 | 40,937 | 7,082 |
| China | r1,574 | 157 | 5,871 | 415 |
| Czechoslovakia | r2,900 | 184 | 2,755 | 175 |
| Greece | r7,448 | 1,026 | 4,331 | 766 |
| Japan | r497 | 24 | -- | -- |
| Mexico | r926 | 108 | 2,111 | 274 |
| Spain | r6,503 | 1,537 | 7,441 | 995 |
| Turkey | r4,801 | 566 | 1,823 | 300 |
| Other | r118 | r81 | 144 | 48 |
| Total | r54,893 | 9,594 | 65,709 | 10,407 |
| Dead-burned and grain magnesia and periclase: |  |  |  |  |
| Not containing lime or not over 4% lime: |  |  |  |  |
| Brazil | 9,573 | 1,528 | 3,161 | 444 |
| China | 30,556 | 4,138 | 44,478 | 5,274 |
| Greece | 48,844 | 7,056 | 37,793 | 5,874 |
| Ireland | 13,984 | 3,569 | 24,729 | 6,822 |
| Japan | 8,129 | 2,550 | 15,049 | 3,964 |
| Mexico | 6,345 | 1,667 | 6,684 | 1,772 |
| Netherlands | 7,209 | 1,806 | 4,947 | 1,347 |
| South Africa, Republic of | 552 | 273 | 122 | 601 |
| United Kingdom | 3,337 | 424 | 25,870 | 3,345 |
| Other | 1,255 | r704 | 717 | 324 |
| Total | 129,784 | r23,715 | 163,550 | 29,767 |
| Containing over 4% lime: |  |  |  |  |
| Austria | 3,739 | 976 | 2,981 | 733 |
| Belgium-Luxembourg | -- | -- | 115 | 37 |
| Canada | 18,352 | 1,007 | 11,239 | 1,267 |
| Germany, Federal Republic of | 547 | 131 | 533 | 160 |
| Greece | 2,205 | 290 | -- | -- |
| Mexico | 394 | 34 | 736 | 94 |
| United Kingdom | 141 | 33 | 20 | 4 |
| Other | -- | -- | 33 | 13 |
| Total | 25,378 | 2,471 | 15,657 | 2,308 |
| Total dead-burned and grain magnesia and periclase | 155,162 | r26,186 | 179,207 | 32,075 |

rRevised.

[1] In addition, crude magnesite was imported as follows, in short tons and thousand dollars: 1984—Australia, 119 (revised) ($30); Canada, 45 (revised) ($9); the Federal Republic of Germany, 20 ($7); Japan, 556 (revised) ($184); Mexico, 12 ($1); and the United Kingdom, 6 ($1). 1985—Austria, 20 ($6); Canada, 49 ($12); the Federal Republic of Germany, 22 ($6); Italy, 1,234 ($300); Japan, 19 ($7); and the United Kingdom, 6 ($1).

Source: Bureau of the Census.

Table 7.—U.S. imports for consumption of magnesium compounds

| Year | Oxide or calcined magnesia | | Magnesium carbonate[1] (precipitated) | | Magnesium chloride (anhydrous) | | Magnesium chloride (other) | | Magnesium sulfate (epsom salts and kieserite) | | Magnesium salts and compounds, n.s.p.f.[2] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1983 | 6,725 | $5,355 | 185 | $235 | 15 | $11 | 1,761 | $282 | 39,405 | $2,539 | 1,988 | $1,858 |
| 1984 | 6,121 | 4,918 | 284 | 395 | 63 | 17 | 2,987 | 347 | 34,255 | 2,621 | 2,443 | 1,738 |
| 1985 | 4,891 | 5,638 | 247 | 351 | 125 | 21 | 2,975 | 368 | 25,691 | 1,902 | 2,822 | 1,806 |

[1] In addition, magnesium carbonate, not precipitated, was imported as follows, in short tons and thousand dollars: 1983—12 ($28); 1984—33 ($63); and 1985—110 ($125).

[2] Includes magnesium silicofluoride or fluosilicate and calcined magnesia.

Source: Bureau of the Census.

## WORLD REVIEW

**Australia.**—Queensland Metal Corp. NL reportedly discovered a large shallow magnesite deposit in central Queensland estimated to contain over 500 million tons of material, with a mean grade of 44.2% magnesium oxide. A prefeasibility study was conducted by Fluor Australia Pty. Ltd. to assess geology, magnesite processing, magnesium metal production, mining, and marketing. Because this is a shallow deposit, it was expected that low-cost surface mining methods may be suitable for ore recovery. Construction of a 110,000-ton-per-year dead-burned magnesia plant was expected to begin in late 1986 or early 1987.[2]

**China.**—A West German firm, Krupp Polysius AG, and an Austrian company, Refractories Consulting and Engineering GmbH, were expected to begin construction of a magnesite sintering plant in May 1986. The plant, with an annual capacity of 55,000 tons, was to be constructed in Liaoning Province for the Liaoning Magnesite Co.'s Haicheng Mine. Plant completion was scheduled for 1988.

**Egypt.**—The Egyptian Salt and Minerals Co. planned to construct a plant to recover mineral salts from Lake Quarun in Fayoum Province. The plant, scheduled to be completed in 1988 at a cost of $80 million, will have an annual capacity of 45,000 tons of magnesium oxide and also was expected to produce sodium chloride, sodium sulfate, and sodium sulfide.

**Greece.**—Grecian Magnesite Ltd. S.A. planned to invest $20 million to improve the efficiency of its magnesite operations. The investment reportedly included expanding the company's annual capacity for dead-burned and caustic-calcined magnesites from 220,000 to 300,000 tons. Improvement of transportation and storage facilities and development of new products also were scheduled as part of the company's modernization plan.

Mining Trading and Manufacturing Ltd. also announced that it will modernize its plants and increase production capacity. The company, which produced both raw and caustic-calcined magnesites, intended to replace equipment and increase annual production from 65,000 to 75,000 tons.[3]

**Japan.**—In April 1985, Asahi Glass Co. began commercial production of high-purity magnesium oxide and magnesium hydroxide from seawater. The company reportedly constructed a plant to produce 3,000 tons per year of 99.1% magnesium hydroxide and 2,000 tons per year of 99.6% magnesium oxide. High-purity magnesium hydroxide is used primarily as a flame retardant filler material, and high-purity magnesium oxide has applications as a resin filler for use in electronics, in ceramics, and as an optical glass material.[4]

**Pakistan.**—A joint venture between the Pakistan Industrial Development Corp. and the Al-Ghurair business house of the United Arab Emirates to construct a magnesia refractories plant was planned. Magnesite from the Hazara division of Pakistan was expected to provide the raw material for the 17,000-ton-per-year plant.

**Spain.**—A review of the magnesite and dolomite producers was published. Caustic-calcined and dead-burned magnesites were produced by three companies. Magnesitas Navarras S.A. had an annual capacity of 65,000 tons of caustic-calcined magnesite and 70,000 tons of dead-burned magnesite at its plant in Zubiri. Magnesitas de Rubián S.A. produced caustic-calcined magnesite for the agricultural market at its 75,000-ton-per-year plant in Monte Castelo. The third producer, Magnesitas Españolas S.A. mined a small quantity of crude magnesite at its operation in Puerto de la Cruz Verde. Spain was a net exporter of magnesite, although special grades of magnesia, such as seawater magnesia for magnesia-carbon bricks and fused magnesite, were imported.[5]

**Yugoslavia.**—A 27,000-ton-per-year magnesium oxide sintering plant reportedly began full-scale production in late January at Kraljevo, Serbia. The plant, owned by Magnohrom, refined low-grade ore into 99% magnesium oxide.

### Table 8.—Magnesite: World production, by country[1]

(Short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Australia | 29,151 | 32,707 | 24,267 | [r] [e]28,000 | 28,000 |
| Austria | 1,277,414 | 1,136,927 | 1,108,668 | 1,304,484 | 1,312,000 |
| Brazil[2] | 314,055 | 248,607 | 254,634 | 259,043 | 259,000 |
| Canada[e] [3] | 76,000 | 75,000 | 74,000 | 76,000 | 75,000 |
| China[e] | 2,200,000 | 2,200,000 | 2,200,000 | 2,200,000 | 2,200,000 |
| Colombia[e] | 1,800 | 1,800 | 1,800 | 1,800 | 1,800 |
| Czechoslovakia | 732,000 | 740,752 | 729,729 | 728,000 | 739,000 |
| Greece | [r]1,060,072 | [r]1,066,051 | 981,618 | 1,173,111 | 1,200,000 |
| India | 499,798 | 448,718 | 478,482 | 456,388 | 463,000 |
| Iran[e] [4] | 4,400 | 5,500 | 5,500 | 5,500 | 5,500 |
| Kenya | [r]11 | -- | NA | 343,098 | 330,000 |
| Korea, North[e] | 2,095,000 | 2,095,000 | 2,095,000 | 2,095,000 | 2,095,000 |
| Mexico | 13,357 | 24,793 | 25,559 | 33,537 | 33,000 |
| Nepal | [e]22,000 | [e]22,000 | 16,552 | 16,097 | 16,500 |
| New Zealand | 340 | ([5]) | -- | -- | -- |
| Pakistan | 1,710 | [r]1,276 | 2,202 | 4,105 | 5,300 |
| Poland | 12,436 | [r]18,739 | 17,747 | [e]18,000 | 18,000 |
| South Africa, Republic of | 62,343 | 35,193 | 24,868 | 36,441 | 28,300 |
| Spain | 525,132 | 588,187 | 658,230 | 762,294 | 717,000 |
| Turkey | [r]864,167 | [r]1,013,653 | 792,698 | 797,261 | 800,000 |
| U.S.S.R.[e] | 2,290,000 | 2,370,000 | 2,400,000 | 2,400,000 | 2,400,000 |
| United States | W | W | W | W | W |
| Yugoslavia | 330,336 | 362,060 | 335,064 | 359,353 | [6]459,663 |
| Zimbabwe | 66,352 | [r]66,866 | 26,534 | 23,856 | 22,000 |
| Total | [r]12,477,874 | [r]12,553,829 | 12,253,152 | 13,121,368 | 13,208,063 |

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Figures represent crude salable magnesite. In addition to the countries listed, Bulgaria produced magnesite, but output is not reported quantitatively, and available general information is inadequate for formulation of reliable estimates of output levels. Table includes data available through May 6, 1986.

[2]Series reflects output of marketable concentrates. Production of crude ore was as follows, in short tons: 1981—681,228; 1982—556,667; 1983—535,723; 1984—551,000 (estimated); 1985—551,000 (estimated).

[3]Magnesitic dolomite and brucite. Figures are estimated on the basis of reported tonnage dollar value.

[4]Year beginning Mar. 21 of that stated.

[5]Revised to zero.

[6]Reported figure.

## TECHNOLOGY

A description of Veitscher Magnesitwerke AG's underground magnesite mine in Brietenau, Austria, was included in a review of the Austrian mining industry. A room-and-pillar system was used for mining the ore, and then the ore was crushed and sintered in a rotary kiln or shaft kiln before being sold. Average annual production for this mine was estimated to be about 500,000 tons.[6]

Mining methods and processing of olivine at A/S Olivin's operation at Aaheim, Norway, were reviewed. Olivin reportedly supplied almost one-half of the world's 5-million-ton olivine demand.[7]

An overview of the fused minerals industry was published, including a discussion of the production, consumption, and uses of fused magnesia. Fused magnesia was used primarily in electrical insulation and refractory applications. Magnesia-alumina spinel material ($MgAl_2O_4$) for refractory applications was produced by fusing high-purity magnesia and Bayer alumina.[8]

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[1] Physical scientist, Division of Nonferrous Metals.

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# Manganese

## By Thomas S. Jones[1]

World production of manganese ore increased to possibly the highest level since the peak year of 1980. Ore production rose in several market economy countries, with Gabon reaching a record high output. U.S. production consisted only of some manganiferous material for brick coloring. There were no U.S. imports of ore from the Republic of South Africa for the first time since shortly before World War II.

Prices of manganese materials were generally static, as supply capabilities continued to exceed demand. Price changes were insignificant both for the increase in price of metallurgical ore on international markets and the decrease in price of ferromanganese imported into the United States.

Further evolution of the manganese potential of the Carajás region of Brazil was marked by the beginning of exports of metallurgical ore. Projects were also under way there for production of manganese ferroalloys, metal, and chemicals in plants to be fed with Carajás ore.

U.S. consumption of ferromanganese decreased by about the same moderate extent as the decline in domestic raw steel production. The rate of manganese consumption in steelmaking also decreased slightly. The U.S. Government extended through 1986 its contract for upgrading ore in the National Defense Stockpile into high-carbon ferromanganese. This program continued aid to a domestic industry that still consisted of only two firms in 1985. Statistics on world production of manganese ferroalloys are presented in the "Ferroalloys" chapter.

**Domestic Data Coverage.**—Domestic production data for manganese are developed by the Bureau of Mines from three separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Manganese and Manganiferous Ores" survey. Of the four operations to which a survey request was sent, all responded, representing 100% of the total production shown in table 3.

**Table 1.—Salient manganese statistics**

(Thousand short tons)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Manganese ore (35% or more Mn): | | | | | |
| Imports for consumption | 639 | 238 | 368 | 338 | 387 |
| Consumption | 1,077 | 609 | 531 | $^{r}$615 | $^{e}$545 |
| Manganiferous ore (5% to 35% Mn): | | | | | |
| Production (shipments) | 175 | 32 | 34 | 88 | 20 |
| Ferromanganese: | | | | | |
| Production | 193 | 119 | 86 | W | W |
| Exports | 15 | 10 | 8 | 7 | 7 |
| Imports for consumption | 671 | 493 | 342 | 409 | 367 |
| Consumption | 821 | 439 | 446 | 492 | 466 |
| World: Production of manganese ore | $^{r}$25,967 | $^{r}$26,701 | 24,190 | $^{p}$26,027 | $^{e}$26,922 |

$^{e}$Estimated. $^{p}$Preliminary. $^{r}$Revised. W Withheld to avoid disclosing company proprietary data.

**Legislation and Government Programs.**—Continuing the program of upgrading stockpiled metallurgical manganese ore into high-carbon ferromanganese, the General Services Administration (GSA) in August extended through December 31, 1986, its stockpile upgrading contract with Elkem Metals Co. Under the extension, 58,600 tons[2] of ore was to be converted into ferromanganese at an estimated cost of $15.8 million. GSA suspended sales of excess materials from the stockpile on October 1 to comply with a statutory restriction prohibiting such sales when the balance in the National Defense Stockpile Transaction Fund exceeds $250 million. Natural battery and metallurgical manganese ore were among the excess stockpile materials for which offers for disposal were withdrawn until further notice. Sales prior to the suspension and changes in stockpile inventories of manganese materials in 1985 are shown below. The change for medium-carbon ferromanganese was just an inventory adjustment.

| Material | Sales (short tons) | | Change in yearend inventory (short tons) |
|---|---|---|---|
| | Stockpile grade | Nonstockpile grade | |
| Natural battery ore | 4,000 | -- | -6,317 |
| Chemical ore | -- | -- | -18,977 |
| Metallurgical ore | -- | -- | -165,431 |
| Medium-carbon ferromanganese | -- | -- | +187 |

**Table 2.—U.S. Government stockpile goals and yearend inventories for manganese materials in 1985**

(Short tons)

| Material | Stockpile goals | Physical inventory, Dec. 31 | | | | |
|---|---|---|---|---|---|---|
| | | Uncommitted | | | Sold, pending shipment | Grand total[1] |
| | | Stockpile grade | Nonstockpile grade | Total | | |
| Natural battery ore | 62,000 | 171,593 | 33,561 | 205,154 | 6,648 | 211,802 |
| Synthetic manganese dioxide | 25,000 | 3,011 | -- | 3,011 | -- | 3,011 |
| Chemical ore | 170,000 | 171,717 | 89 | 171,806 | 1,732 | 173,539 |
| Metallurgical ore | 2,700,000 | 2,279,408 | 942,679 | 3,222,087 | 168,061 | 3,390,148 |
| High-carbon ferromanganese | 439,000 | 624,310 | -- | 624,310 | -- | 624,310 |
| Medium-carbon ferromanganese | -- | 29,057 | -- | 29,057 | -- | 29,057 |
| Silicomanganese | -- | 23,574 | -- | 23,574 | -- | 23,574 |
| Electrolytic metal | -- | 14,172 | -- | 14,172 | -- | 14,172 |

[1] Data may not add totals shown because of independent rounding.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, manganese would be categorized in tier II, and the goal would be about 870,000 tons of manganese metal equivalent. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

The Environmental Protection Agency (EPA) determined in August that the then-present ambient air concentrations of manganese did not pose a significant risk to public health; therefore, regulation directed specifically at manganese was unnecessary at that time under the Clean Air Act. This determination was without effect on existing regulation of particulate matter and did not preclude State and/or local air pollution control agencies from specifically regulating manganese emission sources.[3] EPA also issued a compilation of information on the ways in which manganese may be emitted into the atmosphere from various industrial sources and the potential for manganese release from each source.[4]

The U.S. Congressional Office of Technology Assessment (OTA) ranked manganese within a first group of strategic materials for the United States, along with chromium, cobalt, and the platinum-group metals. OTA concluded that the best prospect for reducing U.S. manganese import vulnerability was through improved steel production technology that would lower the amount of manganese required per ton of steel. OTA also concluded that the potential for reducing uncertainty about supply from the Republic of South Africa was good because of the existence of several alternative suppliers.[5]

Under the Trade and Development Program of its International Development Cooperation Agency, the U.S. Department of State conducted a symposium at which possibilities were suggested for joint Brazilian-U.S. ventures in manganese. Two potential ferromanganese operations were identified, one in the Carajás region of north-central Brazil and the other near Corumba in southwestern Brazil near its borders with Bolivia and Paraguay.

## DOMESTIC PRODUCTION

**Ore and Concentrate.**—No manganese ore, concentrate, or nodules containing 35% or more manganese or ferruginous manganese ores or concentrates containing from 10% to 35% manganese were produced or shipped in the United States. The only mineral production of material containing 5% or more manganese was that mined in Cherokee County, SC, by brick manufacturers or contractors for use in coloring brick. This material consisted of manganiferous schist, clay, or other earthy material associated with the manganiferous member of the Battleground Schist of the Kings Mountain area. The manganese content ranged from 5% to 15% and averaged less than 10%.

**Table 3.—Manganiferous ore shipped[1] in the United States, by type and State**

(Short tons unless otherwise specified)

| Type and State | 1984 Gross weight | 1984 Manganese content | 1985 Gross weight | 1985 Manganese content |
|---|---|---|---|---|
| Ferruginous manganese ore (10% to 35% Mn, natural): | | | | |
| Minnesota | 68,019 | 8,754 | -- | -- |
| Manganiferous iron ore (5% to 10% Mn, natural): | | | | |
| South Carolina[2] | 20,404 | 1,799 | 19,882 | 1,882 |
| Total | 88,423 | 10,553 | 19,882 | 1,882 |
| Value | $860,226 | XX | W | XX |

W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1] Shipments are used as the measure of manganiferous ore production for compiling U.S. mineral production value.

[2] Miscellaneous ore.

**Ferroalloys and Metal.**—Production continued to be generally slack. Operations were curtailed late in the summer at the Marietta, OH, plant of Elkem Metals by a labor dispute that lasted nearly 1 month. The Kingwood, WV, facility of Chemetals Inc. was disabled by a flood on November 4 and was out of production for the rest of the year.

Ownership structure was changed for both manganese ferroalloys producers. Elkem Metals became a wholly owned subsidiary of Elkem A/S of Norway in the first half of the year. Elkem acquired the 10% share in Elkem Metals held by the Jebsen Group of Norway in March, and then in May acquired the remaining outstanding 23% share in Elkem Metals held by a group of four Norwegian companies. Details of organizational changes within the Belgian parent of Chemetals are given under "Belgium" in the "World Review" section of this chapter.

SKW Alloys Inc. announced it will continue to market manganese ferroalloys in the United States but will produce only a limited amount of silicomanganese. SKW Alloys had been producing ferromanganese and silicomanganese at Calvert City, KY, until production workers there began a strike in September 1983 that lasted throughout 1985. The company said that after the strike ended it would produce silicomanganese again, but only until manganese ore on hand or committed for was consumed.

Production quantities tabulated for manganese ferroalloys are net production for shipment outside the producing ferroalloy facility, and do not include that portion of gross production recycled to the furnaces, used as an intermediate in producing medium- or low-carbon ferromanganese, or lost in the plant.

### Table 4.—Domestic producers of manganese products in 1985

| Company | Plant location | Products[1] | | | | Type of process |
|---|---|---|---|---|---|---|
| | | FeMn | SiMn | Mn | $MnO_2$ | |
| Chemetals Inc: | | | | | | |
| Chemicals Div | Baltimore, MD | -- | -- | -- | X | Chemical. |
| Metals Div | Kingwood, WV | X | -- | -- | -- | Fused-salt electrolytic. |
| Elkem Metals Co | Marietta, OH | X | X | X | -- | Electric furnace and electrolytic. |
| Foote Mineral Co | New Johnsonville, TN. | -- | -- | -- | X | Electrolytic. |
| Kerr-McGee Chemical Corp | Hamilton, MS | -- | -- | X | -- | Do. |
| Do | Henderson, NV | -- | -- | -- | X | Do. |
| RAYOVAC Corp: ESB Materials Co. | Covington, TN | -- | -- | -- | X | Do. |
| Union Carbide Corp | Marietta, OH | -- | -- | -- | X | Do. |

[1] FeMn, ferromanganese; SiMn, silicomanganese; Mn, electrolytic manganese metal; $MnO_2$, synthetic manganese dioxide.

### Table 5.—Ferromanganese and silicomanganese produced and shipped in the United States and manganese ore consumed in their manufacture

(Thousand short tons, gross weight, unless otherwise specified)

| Year | Ferromanganese | | | Silicomanganese | | Manganese ore consumed[1] | |
|---|---|---|---|---|---|---|---|
| | Production | | | | | | |
| | Gross weight | Manganese content (average percent) | Shipments | Production | Shipments | Total quantity | Per ton of ferromanganese and silicomanganese made |
| 1981 | 193 | 80 | 188 | 173 | 173 | 743 | 2.0 |
| 1982 | 119 | 82 | 98 | 69 | 83 | 412 | 2.2 |
| 1983 | 86 | 81 | 109 | W | 63 | 283 | W |
| 1984 | W | 82 | W | W | W | W | W |
| 1985 | W | 81 | W | W | W | W | W |

W Withheld to avoid disclosing company proprietary data.

[1] Containing 35% or more manganese (natural); includes ore used in producing manganese metal.

## CONSUMPTION, USES, AND STOCKS

**Ironmaking and Steelmaking.**—The average rate at which manganese was consumed as manganese ore in making pig iron or equivalent hot metal decreased to 0.9 pound per ton of raw steel. This rate was calculated from an estimated consumption of 90,000 tons of manganese ore containing more than 35% manganese, all of foreign origin, in iron blast furnaces and production of 88.3 million tons of raw steel ingots, continuous- or pressure-cast blooms, billets, slabs, etc. Data were not available for the quantity of domestic manganiferous iron ore containing 5% to 10% manganese also consumed in iron blast furnaces. The quantity of manganese ore containing 35% or more manganese used directly in steelmaking was reportedly negligible.

Unit manganese consumption in steelmaking as ferroalloys and metal decreased slightly to approximately the 1983 level. For reported consumption in the production of 89.1 million tons of raw steel and steel castings in 1985, the pounds of manganese consumed per ton of raw steel was 7.7 as ferromanganese, 1.5 as silicomanganese, and 0.1 as metal, for a total of 9.3. In 1984, the corresponding unit consumption in production of 93.5 million tons of raw steel and steel castings totaled 9.5, of which ferromanganese accounted for 7.9; silicomanganese, 1.4; and metal, 0.2.

## Table 6.—U.S. consumption and industry stocks of manganese ore,[1] by use

(Short tons)

| Use | Consumption | | Stocks, Dec. 31 | |
|---|---|---|---|---|
| | 1984 | 1985 | 1984 | 1985 |
| Manganese alloys and metal | W | W | 257,698 | 262,664 |
| Pig iron and steel | 116,953 | [e]90,000 | 96,679 | [e]78,940 |
| Dry cells, chemicals, miscellaneous[2] | W | W | 227,890 | 247,008 |
| Total | [r]615,311 | [e]545,000 | 582,267 | [e]588,612 |

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

[1]Containing 35% or more manganese (natural).

[2]Natural ore, including that consumed in making synthetic manganese dioxide.

## Table 7.—U.S. consumption, by end use, and industry stocks of manganese ferroalloys and metal in 1985

(Short tons, gross weight)

| End use | Ferromanganese | | | Silicomanganese | Manganese metal |
|---|---|---|---|---|---|
| | High carbon | Medium and low carbon | Total | | |
| Steel: | | | | | |
| Carbon | 290,105 | 67,725 | 357,830 | 76,343 | 2,903 |
| Stainless and heat-resisting | 12,483 | (1) | 12,483 | 3,228 | 1,543 |
| Full alloy | 26,000 | 8,379 | 34,379 | 13,653 | 908 |
| High-strength, low-alloy | 26,765 | 7,441 | 34,206 | 5,642 | 626 |
| Electric | (1) | (1) | (1) | (1) | (1) |
| Tool | 275 | (1) | 275 | (1) | 101 |
| Unspecified | 156 | 536 | 692 | 660 | 61 |
| Total steel | 355,784 | 84,081 | 439,865 | 99,526 | 6,142 |
| Cast irons | 15,345 | 973 | 16,318 | 2,583 | W |
| Superalloys | 130 | W | 130 | W | 196 |
| Alloys (excluding alloy steels and superalloys) | 946 | W | 946 | W | [2]17,630 |
| Miscellaneous and unspecified | 7,989 | 294 | 8,283 | 2,669 | 537 |
| Total consumption | 380,194 | 85,348 | 465,542 | 104,778 | 24,505 |
| Total manganese content[3] | 297,000 | 68,000 | 365,000 | 69,000 | 24,500 |
| Stocks, Dec. 31 | 82,829 | 17,035 | 99,864 | 14,207 | 5,271 |

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified" where applicable.

[1]Withheld to avoid disclosing company proprietary data; included with "Steel: Unspecified."

[2]Partly based on data of the Aluminum Association Inc.; not directly comparable with data prior to 1984.

[3]Estimated based on typical percent manganese content (rounded).

**Battery and Miscellaneous Industries.**—Duracell Inc., RAYOVAC Corp., and Union Carbide Corp. all announced significant performance improvements in their alkaline batteries that use synthetic manganese dioxide. Such batteries captured a larger share of both civilian and military battery markets from carbon-zinc dry cells. Synthetic dioxide also was blended with natural ore in carbon-zinc cells and used in specialized chemical applications. Foote Mineral Co. became the fifth domestic producer of synthetic dioxide by starting commercial production of electrolytic manganese dioxide (EMD) at its plant in New Johnsonville, TN, in November. Output at the design capacity rate of 10,200 tons per year was achieved in December. This culminated a $16.9 million program in which part of a plant that had produced electrolytic manganese metal from 1968 to 1983 was converted into a computerized EMD facility equipped with titanium anodes.

Union Carbide sold the welding and cutting systems business of its Linde Div. to L-Tec Co., a new limited partnership affiliated with Integrated Resources Inc. of New York City. Property at Niagara Falls, NY, where manganese-containing welding fluxes are manufactured was included in the sale.

In June, a year-old strike by production workers ended at Carus Chemical Co., La-Salle, IL, a producer of potassium permanganate.

N. K. Industries Inc., a new company in Phenix City, AL, began grinding manganese ore for applications in the brick industry.

## PRICES

**Manganese Ore.**—Prices depend primarily on manganese content but are also influenced by several other factors. These include other chemical constituents, physical character, quantity, delivery terms, ocean freight rates, insurance, inclusion or exclusion of duties if applicable, buyers' needs, and availability of ores having the specifications desired. Trade journal quotations reflect the editors' evaluation of the market.

The price of metallurgical ore increased by only a nominal amount. Negotiations between consumers in Japan and in Western Europe were again drawn out and extended late into the summer. Japanese consumers ended up agreeing to prices averaging less than 1% higher overall for a contract volume about the same as that of 1984. The price averaged over the year for delivery to West European ports was barely 1% greater than that of 1984. The average price, c.i.f. U.S. ports, for metallurgical ore containing 48% manganese was $1.43 per long ton unit, compared with $1.42 in 1984; per metric ton unit, these prices were $1.41 and $1.40, respectively. These prices convert to 6.4 and 6.3 cents per pound of manganese in ore, respectively.

**Manganese Ferroalloys.**—A published list price for domestically produced high-carbon ferromanganese with a minimum manganese content of 78% was not available. The price of comparable imported high-carbon ferromanganese averaged less than 1% lower than that of 1984. For most of 1985, the quoted price was the same as that at yearend 1984, $825 to $335 per long ton of alloy, f.o.b. Pittsburgh or Chicago warehouse, although a peak of $335 to $345 had been reached early in February. A final price of $320 to $330 applied as of late October. The price of imported silicomanganese containing 2% carbon generally declined throughout 1985 to average 10% less than that of 1984. For this material, the price per pound of alloy, f.o.b. warehouse, started 1985 at 18 to 20 cents and ended the year at 15.5 to 16.5 cents. For the same grade of domestically preduced silicomanganese, the only price published was 23.5 cents per pound of alloy, f.o.b. producer, a price unchanged from that set in July 1984.

**Manganese Metal.**—Electrolytic metal from domestic suppliers was quoted throughout 1985 at 80 cents per pound for bulk shipments, f.o.b. shipping point. This price had been reached late in November 1984.

## FOREIGN TRADE

Reported ore exports were presumed to be mostly metallurgical ore obtained from excess Government stocks except for about 13,000 tons of reexports shipped to Canada. About 4,000 tons of ore shipped to Mexico plus about two-thirds of that shipped to destinations other than Mexico and Canada apparently was imported manganese dioxide ore possibly ground, blended, or otherwise classified in the United States. Reported reexports of ore, all apparently metallurgical grade, totaled 20,587 tons, destinations of which included 15,568 tons to Mexico and 4,962 tons to Canada. Exports of ferromanganese and silicomanganese remained insignificant compared with imports of these ferroalloys. Exports of manganese metal increased about one-fourth over those of 1984.

Gabon and Brazil were the leading sources of ore imports, each with about one-third of the total. No receipts were reported from the Republic of South Africa for the first time since 1938. Average grade of imported ore remained nearly the same at 48.8%. The quantity of manganese imported as ore and dioxide was approximately 50% of that imported as ferroalloys and metal. Imports of manganiferous ore consisted of only 15 tons from Mexico having an average manganese content of 30%.

Imports of ferromanganese decreased about one-tenth overall from those of 1984, and the average manganese content of all ferromanganese imports declined from 78.6% to 78.2%. Record high imports of silicomanganese were about one-fifth greater than in 1983-84, with those from the Republic of South Africa triple the 1984 quantity from that country. Imports of unwrought manganese metal receded from the 1984 record high to about the 1978-81 import level.

Reported imports for consumption of spiegeleisen were 270 tons, composed of 188 tons from the Federal Republic of Germany having relatively high unit value and 82 tons from Canada.

Imports of manganese dioxide increased 5% over those of 1984 to another record high, although the value of dioxide imports decreased slightly as overall average unit value declined. All but 83 tons were apparently synthetic dioxide for battery or chemical applications. Imports of other manganese chemicals included 165 tons of manganese sulfate, consisting of 114 tons from Belgium-Luxembourg, 29 tons from Japan, 19 tons from the Federal Republic of Germany, and 4 tons from the United Kingdom. Those from Japan and the Federal Republic of Germany had relatively high unit value. Imports for consumption of potassium permanganate increased to 1,499 tons, of which the principal sources were Spain, 1,091 tons; China, 207 tons; and the German Democratic Republic, 191 tons.

**Tariffs.**—Under section 201(b) of the Trade Act of 1974, the International Trade Commission determined on April 8 that increased imports of potassium permanganate were not a substantial cause or threat of serious injury to the domestic potassium permanganate industry. Carus Chemical, the petitioner and sole domestic producer of potassium permanganate, was thereby precluded from possible import relief under section 203 of the Trade Act of 1974.

Table 8.—U.S. exports of manganese ore, ferroalloys, and metal, by country

(Gross weight)

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Ore and concentrates containing 5% or more manganese: |  |  |  |  |
| Canada | 54,859 | $4,225 | 23,977 | $1,530 |
| France | 109,664 | 6,300 | -- | -- |
| Italy | 38,181 | 2,212 | -- | -- |
| Mexico | 25,987 | 1,705 | 30,020 | 2,379 |
| Other | 8,915 | 1,201 | 2,043 | 377 |
| Total | 237,606 | 15,643 | 56,040 | 4,286 |
| Ferromanganese: |  |  |  |  |
| Canada | 5,498 | 3,745 | 6,165 | 4,158 |
| Mexico | 277 | 241 | 288 | 241 |
| Trinidad and Tobago | 879 | 355 | -- | -- |
| Other | 110 | 55 | 474 | 363 |
| Total | 6,764 | [1]4,397 | 6,927 | 4,762 |
| Silicomanganese: |  |  |  |  |
| Canada | 123 | 97 | 2,149 | 904 |
| Dominican Republic | 466 | 243 | 10 | 9 |
| Mexico | 3,749 | 1,537 | 27 | 41 |
| Trinidad and Tobago | 962 | 345 | 881 | 873 |
| Other | [r]34 | [r]15 | 22 | 32 |
| Total | [1]5,333 | 2,237 | 3,089 | 1,859 |
| Metal including alloys and waste and scrap: |  |  |  |  |
| Belgium-Luxembourg | 1,015 | 1,460 | 932 | 1,304 |
| Canada | 280 | 462 | 429 | 766 |
| Germany, Federal Republic of | 40 | 65 | 400 | 563 |
| Japan | 1,533 | 2,035 | 1,873 | 2,322 |
| Netherlands | 384 | 493 | 888 | 1,215 |
| Sweden | 182 | 256 | 8 | 18 |
| Other | [r]648 | [r]1,145 | 632 | 1,054 |
| Total | 4,082 | [1]5,915 | 5,162 | 7,242 |

[r] Revised.

[1] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census, adjusted by the Bureau of Mines.

## Table 9.—U.S. imports for consumption of manganese ore, ferroalloys, metal, and dioxide, by country

| Country | 1984 Gross weight (short tons) | 1984 Manganese content (short tons) | 1984 Value (thousands) | 1985 Gross weight (short tons) | 1985 Manganese content (short tons) | 1985 Value (thousands) |
|---|---|---|---|---|---|---|
| **ORE AND CONCENTRATES** | | | | | | |
| 35% or more manganese: | | | | | | |
| Australia | 39,689 | 21,005 | $2,670 | 82,948 | 43,104 | $4,490 |
| Brazil | 88,383 | 44,259 | 3,185 | 122,726 | 59,816 | 5,423 |
| Gabon | 132,965 | 66,135 | 6,898 | 129,360 | 64,093 | 8,240 |
| Mexico | 40,831 | [1]16,298 | 2,122 | 51,708 | [1]21,761 | 4,379 |
| Morocco | 77 | [1]39 | 21 | 118 | [1]65 | 29 |
| South Africa, Republic of | 36,179 | 17,286 | 1,178 | -- | -- | -- |
| Total[2] | 338,094 | 165,023 | 16,024 | 386,859 | 188,840 | 22,561 |
| Of which, more than 35% but less than 47% manganese: Mexico | 38,028 | 14,897 | 1,975 | 43,698 | 16,842 | 2,422 |
| **FERROMANGANESE** | | | | | | |
| All grades: | | | | | | |
| Australia | 5,987 | 4,637 | 1,406 | 11,183 | 8,729 | 2,908 |
| Belgium-Luxembourg | 843 | 758 | 787 | -- | -- | -- |
| Brazil | 9,425 | 7,266 | 2,477 | 11,583 | 8,854 | 2,614 |
| Canada | 2,052 | 1,408 | 352 | 36,562 | 28,275 | 9,270 |
| France | 123,081 | 96,445 | 33,271 | 117,708 | 91,905 | 33,196 |
| Germany, Federal Republic of | 24,308 | 19,794 | 11,650 | 10,158 | 8,157 | 3,542 |
| Japan | 2,756 | 2,225 | 1,385 | 212 | 192 | 213 |
| Mexico | 39,124 | 30,876 | 12,715 | 38,071 | 30,401 | 12,548 |
| Norway | 39,844 | 31,920 | 12,092 | 2,894 | 2,512 | 2,616 |
| Portugal | 17,444 | 13,475 | 3,237 | 5,842 | 4,483 | 1,258 |
| South Africa, Republic of | 133,708 | 104,497 | 34,599 | 127,591 | 98,121 | 34,912 |
| Spain | 6,320 | 4,972 | 2,587 | 2,243 | 1,892 | 974 |
| Yugoslavia | 4,519 | 3,427 | 1,120 | 2,921 | 2,225 | 788 |
| Total[2] | 409,310 | 321,689 | 117,678 | 366,874 | 286,744 | 104,889 |
| Of which, 1% or less carbon: | | | | | | |
| Belgium-Luxembourg | 843 | 757 | 787 | -- | -- | -- |
| Canada | 17 | 12 | 2 | 40 | 27 | 5 |
| France | 892 | 790 | 1,012 | 2,389 | 2,113 | 2,239 |
| Japan | -- | -- | -- | 212 | 192 | 213 |
| Norway | 3,268 | 2,872 | 2,753 | 2,895 | 2,512 | 2,616 |
| Spain | -- | -- | -- | 40 | 34 | 26 |
| Total[2] | 5,020 | 4,431 | 4,554 | 5,575 | 4,877 | 5,098 |
| More than 1% to 4% or less carbon: | | | | | | |
| Brazil | 606 | 497 | 297 | -- | -- | -- |
| Canada | 17 | 12 | 2 | 171 | 124 | 32 |
| France | 4,368 | 3,655 | 2,139 | -- | -- | -- |
| Germany, Federal Republic of | 24,308 | 19,794 | 11,650 | 5,204 | 4,269 | 2,310 |
| Japan | 2,756 | 2,225 | 1,385 | -- | -- | -- |
| Mexico | 15,830 | 12,727 | 7,540 | 20,592 | 16,652 | 8,667 |
| South Africa, Republic of | 649 | 527 | 313 | 2,214 | 1,787 | 906 |
| Spain | 4,976 | 3,980 | 2,347 | 2,203 | 1,858 | 948 |
| Total[2] | 53,509 | 43,419 | 25,674 | 30,383 | 24,689 | 12,923 |
| **SILICOMANGANESE** | | | | | | |
| Australia | 14,181 | 9,344 | 4,096 | 14,762 | 9,774 | 4,420 |
| Brazil | 46,591 | 30,565 | 14,190 | 20,315 | 13,471 | 6,204 |
| Canada | 933 | 632 | 302 | 2,249 | 1,388 | 315 |
| France | 413 | 270 | 258 | -- | -- | -- |
| Italy | -- | -- | -- | 551 | 340 | 352 |
| Mexico | 15,447 | 10,311 | 5,002 | 9,656 | 6,358 | 2,855 |
| Norway | 11,854 | 7,680 | 5,137 | 13,635 | 8,948 | 5,675 |
| Portugal | 827 | 498 | 141 | 2,425 | 1,642 | 770 |
| Romania | 9,094 | 6,066 | 3,011 | -- | -- | -- |
| South Africa, Republic of | 23,425 | 15,694 | 7,133 | 71,736 | 48,133 | 21,365 |
| Spain | 1,266 | 820 | 765 | 1,475 | 958 | 916 |
| Sweden | -- | -- | -- | 1 | 1 | 1 |
| Thailand[3] | -- | -- | -- | 1,320 | 858 | 600 |
| United Kingdom | -- | -- | -- | 41 | 23 | 5 |
| Yugoslavia | 14,465 | 9,459 | 4,711 | 27,856 | 17,827 | 8,545 |
| Total[2] | 138,494 | 91,389 | 44,746 | 165,523 | 109,719 | 51,423 |

See footnotes at end of table.

## Table 9.—U.S. imports for consumption of manganese ore, ferroalloys, metal, and dioxide, by country —Continued

| Country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Gross weight (short tons) | Manganese content (short tons) | Value (thousands) | Gross weight (short tons) | Manganese content (short tons) | Value (thousands) |
| **METAL** | | | | | | |
| Unwrought: | | | | | | |
| South Africa, Republic of | 13,295 | XX | $12,951 | 8,402 | XX | $ 8,890 |
| Other | 19 | XX | 27 | 164 | XX | 162 |
| Total | 13,314 | XX | 12,978 | 8,566 | XX | 9,052 |
| Waste and scrap: Japan | -- | XX | -- | 4 | XX | 2 |
| **DIOXIDE** | | | | | | |
| Belgium-Luxembourg | 453 | XX | 381 | 439 | XX | 401 |
| Brazil | 788 | XX | 908 | 505 | XX | 612 |
| Greece | 2,600 | XX | 3,112 | 2,386 | XX | 2,625 |
| Ireland | 218 | XX | 302 | 933 | XX | 1,190 |
| Japan | 19,884 | XX | 25,165 | 19,429 | XX | 23,805 |
| South Africa, Republic of | 74 | XX | 77 | 1,888 | XX | 1,490 |
| Other | [r]480 | XX | [r]431 | 90 | XX | 31 |
| Total[2] | 24,498 | XX | 30,378 | 25,671 | XX | 30,154 |

[r] Revised. XX Not applicable.

[1] Includes Bureau of Mines conversion of part of reported data (from apparent $MnO_2$ content to Mn content).

[2] Data may not add to totals shown because of independent rounding.

[3] Country of transshipment rather than original source.

Source: Bureau of the Census, adjusted by the Bureau of Mines.

## Table 10.—U.S. import duties on manganese materials

| Item | TSUS No. | Most favored nation (MFN) | | Non-MFN |
|---|---|---|---|---|
| | | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Ore and concentrate | 601.27 | Free | Free | 1 cent per pound Mn. |
| Ferromanganese: | | | | |
| Low-carbon | 606.26 | 2.4% ad valorem[1] | 2.3% ad valorem | 22% ad valorem. |
| Medium-carbon | 606.28 | 1.4% ad valorem[1] | 1.4% ad valorem | 6.5% ad valorem. |
| High-carbon | 606.30 | 1.5% ad valorem[2] | 1.5% ad valorem | 10.5% ad valorem. |
| Silicomanganese | 606.44 | 4.4% ad valorem[1] | 3.9% ad valorem | 23% ad valorem. |
| Metal | 632.30 | 14% ad valorem | 14% ad valorem[3] | 20% ad valorem. |

[1] Free from certain countries under Generalized System of Preferences, not including Brazil for silicomanganese.

[2] As of Sept. 1, 1985, free for products of Israel.

[3] 5.6% ad valorem for products of Israel.

## WORLD REVIEW

**Australia.**—Manganese ore production increased 9% to the highest level since 1980, according to preliminary data of the Australian Bureau of Mineral Resources. Shipments by Groote Eylandt Mining Co. Pty. Ltd. declined, however, to about 1,540,000 tons for exports and to about 350,000 tons for domestic shipments, for a total of about 1,900,000 tons. This was more than 8% below the 1984 total.[6]

**Belgium.**—Production facilities for manganese chemicals and ferroalloys were included when Société Générale de Belgique SA consolidated its main chemical subsidiaries into Gechem in the final months of the year. In the restructuring, Société Européenne des Dérivés du Manganèse SA (Sedema) was absorbed from Société Carbochimique SA (Carbochim) into Société d'Applications de la Chimie de l'Electricité et des Métaux SA (Sadacem). Principal ownership of Sadacem was divided between Carbochim, 65%, and Gechem, 26%. Gechem owned 99% of Carbochim. A Gechem business sector was formed that included the Sadacem chemical plant at Tertre and Chemetals in the United States, both of which had been owned by Sedema, and the manganese ferroalloy plant of Belgische Vennootschap voor Mangaanproduktie SA (Belgomang) at Langerbrugge. Ownership of Belgomang was shared equally between Sadacem and a state-owned company.

Earlier in the year, the chemical plant at Tertre had raised its production capacities for manganese sulfate solution and manganese sulfate monohydrate ($MnSO_4 \cdot H_2O$) powder to 79,400 and 16,500 tons per year, respectively, both expressed as $MnSO_4 \cdot H_2O$ equivalent.

**Brazil.**—Overall shipments of manganese ore from the Serra do Navio, Amapá Territory, operations of Indústria e Comércio de Minérios S.A. rose slightly to 1,013,000 tons, all via Porto de Santana on the Amazon River. Exports increased to 815,000 tons. Destinations were Europe, 520,000 tons; North America, 162,000 tons; Asia, 87,000 tons; and South America, 45,000 tons. Shipments in coastal vessels to Brazilian consumers declined to 198,000 tons.[7]

Inauguration of the railroad from the Carajás mineral province to ocean shipping facilities at São Luis at the end of February marked another advance in development of the Igarapé Azul deposit. Ore production from this deposit by Cia. Vale do Rio Doce rose to about 228,000 tons, of which 211,000 tons was metallurgical grade and 17,000 tons was battery grade. Metallurgical ore exports were 60,000 tons, beginning with a shipment of 11,000 tons to the United Kingdom in July. This ore was medium grade and typically analyzed about 45% manganese and unusually high alumina, about 10%.

Upgrading of Carajás ore into manganese ferroalloys was the objective of plants announced by two Brazilian ferroalloy producers, Cia. Paulista de Ferro-Ligas and Prometal Produtos Metalúrgicos S.A. Each company planned for a plant rated at a ferromanganese-silicomanganese output of about 40,000 tons per year, to be located in the region and to begin producing in the 1986-88 period. Technical feasibility of producing both standard ferromanganese and silicomanganese beginning with feed material from the Azul deposit and using charcoal as a reductant was demonstrated in pilot plant experiments.[8]

Production of manganese ferroalloys increased to another record high total of about 350,000 tons, according to preliminary data.

Production of manganese materials other than ferroalloys from Carajás ore was preindicated by formation of Metalman S.A. within the Metalur Group. Initial objective of Metalman was to construct a plant capable of producing 5,000 tons per year of electrolytic manganese metal in the Rosário region of Maranhão State. Production was scheduled to begin by mid-1987, with the possibility of expanding within a few years to a capacity of 20,000 tons per year of metal, 12,000 tons per year of electrolytic manganese dioxide, and 1,000 tons per year of potassium permanganate, all largely for export.

**Canada.**—In the first half of the year, Elkem Metals Canada Inc. came under full ownership by Elkem of Norway upon Elkem's acquisition of the 10% share formerly held by the Jebsen Group, also of Norway. The assets of Elkem Metals Canada included a manganese ferroalloy plant at Beauharnois in the Province of Quebec.

**European Economic Community.**—The problem of surplus capacity for high-carbon ferromanganese was still not resolved. At midyear, the Commission of the European Community issued "General Objectives Steel 1990," a working document that projected declines in manganese consumption in ironmaking and steelmaking. Use of manganese ore in iron blast furnaces was foreseen to end in the near future. Rate of use of high-carbon ferromanganese in steelmaking was forecast to decrease, a trend expected to adversely affect Community producers of this ferroalloy.

**France.**—Blast furnace production of high-carbon ferromanganese plus a small amount of spiegeleisen was virtually unchanged at 366,000 tons, according to preliminary data.

Société du Ferromanganèse de Paris-Outreau (SFPO) continued with plasma-assist in commercial blast furnace production of high-carbon ferromanganese. The practice was begun in the latter part of 1984 by attaching a plasma torch to each of three of the nine tuyeres on one of the blast furnaces at SFPO's Boulogne plant. The torches were operated at a power level of up to 1.5 megawatts to superheat the blast. Because of seasonal fluctuation in electric power prices, SFPO tended to emphasize plasma usage during the warmer months when revenue from sales of the plant's surplus electricity was the least.[9]

Early in the year, Société Française d'Électrométallurgie (Sofrem), a subsidiary of Pechiney and a manufacturer of "Gimel metal" and refined ferromanganese, was renamed Pechiney Électrométallurgie.

**Gabon.**—Production of manganese ore at the Moanda Mine of Compagnie Minière de l'Ogooué S.A. (Comilog) increased about 10% to surpass slightly that in the former record high year of 1979. Shipments by Comilog also advanced to about 2,450,000 tons.

**Ghana.**—Exports of manganese ore produced at the Nsuta Mine of Ghana National Manganese Corp. rose somewhat to 291,000 tons. Shipments through the Port of Takoradi were reported as having gone to eight European countries, Japan, and the United States.[10] Shipments in 1985 were approximately double those in the recent low-point year of 1982, having increased every year since.

**Greece.**—Production of battery ore from the Plavista Mine was to be expanded severalfold by C. Christoforidis Mining S.A., its new owner, from a 1985 production level of about 10,000 tons. Grade of the battery ore concentrate was about 72% manganese dioxide. Plans were also made to produce a manganese carbonate ore containing about 32% manganese.[11] The mine is situated on the eastern Khalkidhiki Peninsula near Neochorio.

**Japan.**—Ore production dropped by nearly two-thirds following closure in late 1984 of two mines in Hokkaido Prefecture. These were the Ooe and Inakunaishi Mines of Hokushin Mining Co. Ltd. that had been producing carbonate ore. Chugai Mining Co. Ltd., operator of the Jokoku Mine, thus became the largest domestic ore producer.

Production of manganese ferroalloys decreased about 8%, dropping to 487,000 tons for ferromanganese and to 239,000 tons for silicomanganese. Exports of both materials remained comparatively small, approximately 29,000 tons for ferromanganese and 190 tons for silicomanganese. Imports declined again for ferromanganese, to about 6,500 tons, whereas those of silicomanganese rose to about 134,000 tons. At midyear, Mizushima Gokintetsu began production of high-carbon ferromanganese in a shaft furnace sited within a steelmaking complex of parent company Kawasaki Steel Corp. Demand for manganese ferroalloys continued to decrease owing to steelmakers' hot metal pretreatment practices, especially at Nippon Steel Corp.[12]

The trend of successive increases to new record high totals continued for synthetic manganese dioxide, with production up slightly to 54,000 tons and exports up by one-fifth to 48,400 tons. Both Chuo Denki Kogyo Co., a manganese ferroalloy producer, and Toho Zinc Co. Ltd. announced plans to move into production of chemical manganese dioxide and possibly other manganese chemicals. Production of electrolytic manganese metal rose to 5,100 tons.

**Norway.**—Elkem increased to 100% its ownership of both Elkem Metals Canada and Elkem Metals in the United States, thereby completing the takeover begun in 1983 of the bulk ferroalloy business in North America formerly held by Union Carbide.

**South Africa, Republic of.**—Ore production was relatively steady through the year, well below capacity at a level attained as of mid-1984. Compared with 1984, production overall and production of metallurgical ore increased about one-fifth, whereas production of chemical ore decreased about one-fifth. Production of the various categories of ore was as follows:

|  | Quantity (thousand short tons) |
|---|---|
| METALLURGICAL ORE |  |
| 30% to 40% Mn | 1,589 |
| Over 40% to 45% Mn | 923 |
| Over 45% to 48% Mn | 235 |
| Over 48% Mn | 1,047 |
| Total | [1]3,795 |
| CHEMICAL ORE |  |
| 35% $MnO_2$ and less | 42 |
| Over 35% to 65% $MnO_2$ | 131 |
| Over 65% to 75% $MnO_2$ | 1 |
| Total | 174 |

[1] Data do not add to total shown because of independent rounding.

At its midyear annual meeting, South African Manganese Amcor Ltd. shortened its name to SAMANCOR Ltd. Earlier in the year, SAMANCOR had combined separate divisions for manganese ore and manganese ferroalloys into a single unit. SAMANCOR produced manganese ore from its Hotazel, Mamatwan, and Wessels Mines.

The Associated Manganese Mines of South Africa Ltd. shipped about 1,240,000 tons of manganese ore, a 6% decrease from shipments of about 1,320,000 tons in 1984.[13]

## Table 11.—Manganese ore: World production, by country[1]

(Thousand short tons unless otherwise specified)

| Country[2] | Range percent Mn[e] [3] | Gross weight |  |  |  |  | Metal content |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | 1981 | 1982 | 1983 | 1984[p] | 1985[e] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
| Australia[4] | 37-53 | 1,555 | 1,238 | 1,510 | 2,016 | [5]2,192 | 754 | 594 | 754 | 953 | 1,070 |
| Brazil[6] | 38-50 | [7]2,251 | [7] [8]2,580 | [7]2,306 | [7] [8]2,969 | 2,976 | 900 | 1,032 | 922 | 1,187 | 1,190 |
| Bulgaria | 29 | 50 | 50 | 50 | 50 | 50 | 15 | 15 | 14 | 14 | 14 |
| China[e] [9] | 30 | 1,760 | 1,760 | 1,760 | 1,760 | 1,760 | 530 | 530 | 530 | 530 | 530 |
| Gabon[6] [10] | 50-53 | 1,640 | 1,667 | 2,047 | 2,336 | [5]2,592 | 757 | 769 | 945 | 1,078 | 1,196 |
| Ghana[6] | 30-50 | 246 | 176 | 191 | 296 | 338 | 98 | 71 | 76 | 118 | 135 |
| Hungary[6] [11] | 30-33 | 78 | 91 | 65 | 74 | 72 | 23 | 27 | 20 | 22 | 22 |
| India[6] [10] [12] | 10-54 | 1,682 | [r]1,642 | 1,455 | 1,192 | [5]1,257 | 618 | 603 | 535 | 438 | 462 |
| Japan | 24-27 | 96 | 86 | 83 | 68 | [5]23 | 23 | 22 | 22 | 18 | [5]6 |
| Mexico | 27-50 | [e]637 | [e]561 | [e]386 | [r] [e]525 | 511 | 229 | 202 | 147 | 199 | 194 |
| Morocco[6] | 50-53 | 121 | 106 | 81 | 63 | [5]48 | 64 | 56 | 43 | 33 | 26 |
| Romania[6] | 30 | 63 | 61 | 86 | 73 | 73 | 19 | 18 | 26 | 22 | 22 |
| South Africa, Republic of[6] [10] | 30-48+ | 5,555 | 5,750 | 3,181 | 3,361 | [5]3,969 | 2,123 | 2,220 | 1,225 | 1,341 | 1,587 |
| Thailand[6] | 46-50 | 12 | 9 | 7 | 10 | 9 | 6 | 4 | 4 | 5 | 4 |
| Turkey[6] | 27-46 | 16 | 8 | 4 | 47 | 55 | 6 | 3 | 1 | 17 | 19 |
| U.S.S.R | 29-30 | 10,090 | 10,830 | 10,890 | 11,100 | 10,900 | 3,043 | 3,260 | 3,280 | 3,300 | 3,200 |
| Yugoslavia | 25-45 | 34 | [r]30 | 35 | [e]30 | 28 | 12 | 11 | 12 | [e]11 | 10 |
| Other[e] [13] | XX | [r]80 | 56 | 54 | [r]60 | 69 | [r]32 | 22 | 20 | [r]23 | 25 |
| Total[14] | XX | [r]25,967 | [r]26,701 | 24,190 | 26,027 | 26,922 | [r]9,254 | [r]9,460 | 8,575 | 9,310 | 9,713 |

[e]Estimated. [p]Preliminary. [r]Revised. XX Not applicable.

[1] Table includes data available through June 10, 1986.

[2] In addition to the countries listed, Colombia, Cuba, and Namibia may have produced manganese ore and/or manganiferous ore, but available information is inadequate to make reliable estimates of output levels. Low-grade ore not included in this table has been reported as follows, in thousand short tons, gross weight: Argentina (19% to 30% Mn), 1981—3, 1982—4, 1983—8, 1984—9, and 1985—8, and Czechoslovakia (about 17% Mn), an estimated 1 in each year.

[3] May be for average content of each year's production rather than for content of typical products.

[4] Metallurgical ore.

[5] Reported figure.

[6] Gross weight reported; metal content estimated. Estimated metal content figures have been revised as necessary.

[7] Figures are the sum of (1) sales of direct-shipping manganese ore and (2) production of beneficiated ore, both as reported in Anuário Mineral Brasiliero.

[8] Only about two-thirds of this quantity was marketed.

[9] Includes manganiferous ore.

[10] Calculated metal content includes allowance for assumed moisture content.

[11] Concentrate.

[12] Much of India's production grades below 35% Mn; average content was reported as 37.5% Mn in 1981-82.

[13] Category represents the combined totals of Bolivia (exports), Chile, Greece, Indonesia, Italy (from wastes), the Republic of Korea, Pakistan, the Philippines, Sudan, and Zaire.

[14] Data may not add to totals shown because of independent rounding.

Effective August 1, the world's two largest producers of electrolytic manganese metal, Electrolytic Metal Corp. (Pty.) Ltd. (Emcor) and Delta Manganese (Pty.) Ltd. (Deltamang), were merged into a single firm, Manganese Metal Co. (Pty.) Ltd. (MMC). MMC's metal capacity of about 48,000 tons per year, all in Transvaal Province, consisted of the former Emcor plant at Krugersdorp and the former Deltamang plant at Nelspruit, the newer and larger of the two with a capacity about 160% that of the Krugersdorp plant.[14] At the time of the merger, Emcor was controlled by General Mining Union Corp. Ltd., and Deltamang was controlled by Delta S.A. (Pty.) Ltd. Division of ownership of MMC was Emcor, 51%, and Delta S.A., 49%. Delta EMD (Pty.) Ltd., formerly a subsidiary of Deltamang and the country's only producer of electrolytic manganese dioxide, was not merged into MMC but remained a subsidiary of Delta S.A.

**U.S.S.R.**—Mine production declined slightly, and the percentage decline was apparently somewhat greater for the Chiatura Basin in Georgia than for the Nikopol' Basin in the Ukraine. Various methods of beneficiating high-clay, low-grade ores of the Nikopol' and Chiatura Basins containing about 20% manganese were being developed. High-gradient magnetic separation (HGMS) was being tested for Chiatura ores. Application of chemical benefication to Nikopol' ores showed that high-grade concentrates low in phosphorus could be produced by a dithionate process.[15] In 1984, the overall average grade of concentrates had fallen to a little under 30%.

Kazakhstan's contribution to Soviet manganese mine production remained insignificant but was being increased. In 1984, the open pit Ushkatyn-1 Mine in central Kazakhstan was brought into operation, adding its capacity of nearly 1 million tons of crude ore per year to output from the Dzhezdy manganese mine and the Karazhal iron-manganese deposit.

The quantity of ore exported in 1984, 1,192,000 tons, was virtually the same as that in 1983. Principal destinations, accounting for over 90% of the total, were, in tons, Poland, 605,000; Czechoslovakia, 331,000; Bulgaria, 82,000; and the German Democratic Republic, 75,000.

**United Kingdom.**—Sale of about one-fourth of a Government stockpile of strategic materials in the second half of the year included about 26,000 tons of high-carbon ferromanganese, 29,000 tons of manganese ore fines, and 1,400 tons of battery ore.

## TECHNOLOGY

In a report on deposits of strategic and critical minerals in Nevada, the Bureau of Mines listed data on five deposits that have a potential for commercial production of manganese: Boulder City, Fannie Ryan, Gibellini, Three Kids, and Virgin River. Except for Gibellini, all of these deposits are in the southeast corner of Nevada east of Las Vegas. Three Kids is a past producer; the other deposits are inactive and have been explored only.[16]

The Bureau summarized its research on analysis and characterization of ocean manganese nodules and potential rejects from nodule processing. This research, funded by the National Oceanic and Atmospheric Administration, gave a positive indication that commercial recovery of cobalt, copper, manganese, and nickel from manganese nodules would be environmentally acceptable.[17] Tailings and slags characterized by the Bureau were generated by processing nodules in the laboratory according to five proposed first-generation processes. Pacific manganese nodules from the Clarion-Clipperton fracture zone served as feed material for these tests.[18]

Hypothetical mining of nodules from this portion of the northeast equatorial Pacific Ocean and subsequent metal recovery were subjected to cost sensitivity analysis by the Bureau. It was concluded that, for the foreseeable future, significant financial incentives would be required to make nodule mining and processing economically attractive.[19]

Tables of thermodynamic data on elemental manganese and various manganese borides, carbides, carbonates, chlorides, fluorides, nitrides, oxides, phosphides, selenides, silicates, silicides, sulfides, and tellurides were included in a Bureau compilation of thermodynamic data.[20]

HGMS was investigated as a method for utilizing the manganese resource of the Cuyuna iron ore range in central Minnesota. Tests were conducted on samples of the major types of manganiferous ore found in the north range district of the Cuyuna Range. Fine grinding, such as to 85% minus

500 mesh, enhanced liberation of manganese minerals. Hematite ore responded best to HGMS, yielding a product with 21% manganese and 32% iron at a manganese recovery of about 80% from an ore feed with 13% manganese and 29% iron.[21]

Expansion of India's manganese resource base by pan sintering ore fines was evaluated. This method of agglomeration was considered for fines of high-grade manganese ore and beneficiated low-grade manganese ore. Laboratory-scale through semicommercial-scale tests were conducted, as well as smelting trials in a commercial ferromanganese furnace. These tests indicated pan sintering was suitable for the limited quantities of manganese fines produced during processing of a variety of Indian ores.[22]

Modification of a conventional composition of Hadfield steel resulted in an as-cast steel that was successfully field tested in France for use in rail frogs, and led to similar applications elsewhere in Europe and Africa. A manganese-molybdenum steel was derived from the Hadfield steel composition with about 13% manganese by lowering carbon content from 1.2% to about 0.8% and adding 1.0% to 1.8% molybdenum. The modified composition eliminated the need for heat treatment that is required during both installation and repair of conventional steel frogs.[23]

The possibility that the residual limits for manganese in aluminum casting alloys could be raised in the future was discussed in light of the growing significance of recycling manganese-bearing used beverage cans. Further investigation is needed, but a review of the effects of manganese in aluminum alloys for casting was encouraging. In a number of instances, addition of manganese has been found to improve alloy properties.[24]

Discovery that rapid solidification of aluminum-manganese alloys can produce atomic arrangements that are neither crystalline nor glassy has attracted considerable scientific interest. The first such nonperiodic or "quasicrystal" structure found has icosahedral symmetry.[25] Further work has revealed existence of a decagonal phase that is structurally intermediate between icosahedral and fully crystalline symmetries.[26] These unusual structures have been produced in aluminum-manganese compositions having 10 to 22 atomic percent manganese.

A review of nonmetallurgical manganese ore production and markets for such ore and manganese compounds pointed out the increasing number of sources of battery ore. A conserative outlook for the synthetic manganese dioxide industry was advocated.[27]

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[1] Physical scientist, Division of Ferrous Metals.

[2] Unless otherwise stated, the unit of weight in this chapter is the short ton of 2,000 pounds.

[3] Federal Register. Environmental Protection Agency. Decision Not To Regulate Manganese Under the Clean Air Act. V. 50, No. 156, Aug. 13, 1985, pp. 32627-32628.

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# Mercury

## By Linda C. Carrico[1]

Domestic mercury mine production, reported by four mines in Nevada, decreased for the fifth consecutive year. Secondary production increased 5%, reflecting the resumption of secondary mercury sales by the General Services Administration (GSA). Imports for consumption decreased 25% from the high level of 1984, with Spain continuing to be the dominant supplier. Reported consumption was virtually the same as that of 1984, with the battery industry accounting for more than 50% of total demand. A buildup of industry stocks, especially during the first half of the year, contributed to the decrease in the domestic dealers' price during that period. As the domestic supply of mercury remained ample during 1985, the average dealers' price declined for the fourth consecutive year. Owing to a worldwide oversupply, the London price plunged below the $300 per flask level in early January and never regained that level.

**Domestic Data Coverage.**—Domestic data for mercury are developed by the Bureau of Mines from three separate, voluntary surveys of U.S. operations. Typical of these surveys is "Mercury," a survey of mercury consumption. Of the 362 firms to which this survey report was sent, 93% responded, representing an estimated 99.6% of the reported U.S. consumption shown in tables 1 and 4. Consumption for the 26 nonrespondents was estimated using prior years' consumption levels.

**Table 1.—Salient mercury statistics**

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Producing mines | 3 | 3 | 3 | 3 | 4 |
| Mine production flasks | 27,904 | 25,760 | 25,070 | 19,048 | 16,530 |
| Value thousands | $11,549 | W | W | W | W |
| Secondary production: | | | | | |
| Industrial flasks | 4,244 | 4,473 | 13,751 | $^{r}$5,673 | 5,358 |
| Government[1] do | 7,000 | -- | -- | -- | 585 |
| Industry stocks, yearend[2] do | 27,339 | 28,827 | 31,018 | $^{r}$27,255 | 27,985 |
| Shipments from the National Defense Stockpile[3] do | -- | 7,076 | 6,000 | 4,092 | 4,534 |
| Imports for consumption do | 12,408 | 8,916 | 12,786 | 25,327 | 18,890 |
| Exports do | NA | NA | NA | NA | NA |
| Consumption do | 59,244 | 48,943 | 49,138 | $^{r}$54,669 | 53,483 |
| Price: New York, average per flask | $413.89 | $370.93 | $322.44 | $314.38 | $310.96 |
| Employment, mine and mill, average | 48 | 45 | 45 | 41 | 35 |
| World: | | | | | |
| Mine production flasks | $^{r}$210,885 | $^{r}$197,901 | 180,800 | $^{p}$195,286 | $^{e}$196,250 |
| Price: London, average per flask | $417.52 | $376.96 | $313.33 | $306.40 | $288.56 |

$^{e}$Estimated. $^{p}$Preliminary. $^{r}$Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1] Secondary mercury released from U.S. Department of Energy stocks.

[2] Stocks at mines, consumers, and dealers.

[3] Primary mercury.

**Legislation and Government Programs.**—Public Law 98-525 of 1984 authorized GSA to dispose of 5,000 flasks[2] of excess mercury and 500,000 pounds of excess mercuric oxide from the National Defense Stockpile (NDS) during fiscal year 1985.

GSA auctioned mercury on an "as-is" basis from the NDS on the third Tuesday of each month, offering 1,500 flasks per month. GSA sold 4,499 flasks and shipped

4,534 flasks during the year, leaving 159,189 flasks in excess to the stockpile goal. In June, GSA sold its last authorized (Public Law 98-525) quantity of mercury from the NDS for fiscal year 1985. The stockpile goal remained at 10,500 flasks.

GSA continued to auction 50,000 pounds of mercuric oxide on the first Wednesday of each month from the NDS on an "as-is" basis. The monthly auctions took place through September, when GSA terminated the mercuric oxide disposal program by selling the remaining excess quantity in the stockpile. GSA sold 350,875 pounds of mercuric oxide and shipped 390,822 pounds, with 80 pounds remaining to be shipped at yearend. From the inception of the mercuric oxide disposal program in 1981 through 1985, the following quantities were sold, in pounds: 1981—none; 1982—1,000; 1983—none; 1984—359,100; and 1985—350,875. The total quantity sold was 710,975 pounds.

On October 15, after a lapse of 3 years, GSA resumed monthly auctions of surplus secondary mercury managed by the U.S. Department of Energy (DOE) in Oak Ridge, TN. On the third Tuesday of each month, GSA offered a maximum of 1,500 flasks on an "as-is" basis. GSA sold and shipped 585 flasks, leaving 34,720 flasks available for disposal.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. Mercury was included in tier I of the proposal with no goal listed, pending Government review. The Department of Defense Authorization Act, 1986 (Public Law 99-145),[3] signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

The Environmental Protection Agency (EPA) issued final regulations under the Clean Water Act for certain nonferrous metals manufacturing operations that limit the discharge of pollutants into navigable waters and into publicly owned treatment works by existing and new operations. This regulation provides effluent limitations based on best practicable and best available technology, new source performance standards based on best demonstrated technology, and pretreatment standards for existing and new indirect discharges. The maximum effluent limitations for primary and secondary mercury manufacturing facilities, based on a daily and monthly average, varied according to the type of operation and effluent source.[4] This regulation became effective November 4, 1985.

Under section 304 of the Clean Water Act, EPA announced the availability of final ambient water quality criteria documents for nine pollutants, of which mercury was included. These criteria reflect the latest scientific knowledge on the identifiable effects of pollutants on public health and welfare and aquatic life.[5]

EPA continued its review of the national emission standards, under section 112 of the Clean Air Act, for mercury-cell chlor-alkali plants, sludge incineration and drying plants, and mercury ore processing plants.

On September 30, Public Law 96-510, the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund), expired. Attempts to reauthorize the Superfund prompted legislative action, and at yearend, several bills were under consideration by Congress.

## DOMESTIC PRODUCTION

Since 1982, Nevada has been the only mercury producing State. Total reported mine production in 1985, including byproduct mercury, was 16,530 flasks, with producers operating at 47% of capacity. Production decreased as a result of increased imports over the past 2 years and sales of excess mercury and mercuric oxide from the NDS.

Four mines were in operation during the year: the McDermitt, the Carlin, the Pinson, and the Borealis. The McDermitt Mine, operated by Placer U.S. Inc., remained the principal domestic mercury producer. The Carlin Mine, operated by Carlin Gold Mining Co., the Pinson Mine, operated by Pinson Mining Co., and the Borealis project, operated by Tenneco Minerals Co., produced mercury as a byproduct from their gold mining operations.

Placer continued exploration work at its McDermitt Mine and at other prospects in the Western States. At yearend, the McDermitt Mine had about 6 years of proven reserves, based on an annual production rate of 15,000 flasks.

Waste stripping at FMC Corp.'s Paradise Peak open pit mine near Gabbs, NV, was under way in late 1985. Construction of the mill and leach facility was about 85% completed by yearend, with startup scheduled for June 1986. FMC's geologists predicted that the mine could yield between 800 and 2,600 flasks of mercury per year as a byproduct from gold mining.

**Table 2.—Mercury ore treated and mercury produced in the United States[1]**

| Year | Ore treated (short tons) | Mercury produced | |
|---|---|---|---|
| | | Flasks | Pounds per ton of ore |
| 1981 | 262,380 | 27,888 | 8.1 |
| 1982 | 300,978 | 25,704 | 6.5 |
| 1983 | 335,389 | 25,033 | 5.7 |
| 1984 | 216,212 | 19,014 | 6.7 |
| 1985 | 182,885 | 16,337 | 6.8 |

[1] Excludes mercury produced from old surface ores, dumps, and placers, and as a byproduct.

**Table 3.—Production of secondary mercury in the United States**

(Flasks)

| Year | Industrial production | GSA releases | Total |
|---|---|---|---|
| 1981 | 4,244 | 7,000 | 11,244 |
| 1982 | 4,473 | -- | 4,473 |
| 1983 | 13,751 | -- | 13,751 |
| 1984[r] | 5,673 | -- | 5,673 |
| 1985 | 5,358 | 585 | 5,943 |

[r] Revised.

The following five companies redistilled purchased primary and/or processed purchased scrap mercury: Adrow Chemical Co., Wanaque, NJ; Bethlehem Apparatus Co. Inc., Hellertown, PA; D. F. Goldsmith Chemical and Metal Corp., Evanston, IL; Mercury Refining Co. Inc., Albany, NY; and Troy Chemical Corp., Newark, NJ. Total secondary production from industry and government materials was equivalent to 11% of the reported mercury consumption. Major sources of secondary mercury were amalgams, sludges, obsolete industrial and control instruments, metal retrieved from chlorine and caustic soda plants, and mercuric oxide from the NDS.

## CONSUMPTION AND USES

Consumption of mercury was reported by about 275 plants, of which more than one-half were east of the Mississippi River. Primary mercury accounted for 68% of the total reported consumption, followed by redistilled mercury,[6] 22%, and secondary mercury, 10%.

Domestic mercury consumption was virtually the same as that of 1984, with the battery industry continuing to be the dominant consumer, followed by industries producing chlorine and caustic soda, paints, wiring devices and switches, and measuring and control instruments.

Mercury consumed by the chlorine and caustic soda manufacturing industry declined because of the permanent closing of three mercury-cell chlor-alkali plants and the temporary closure of one plant. The following mercury-cell chlor-alkali plants closed during 1985: LCP Chemicals and Plastics Inc., Linden, NJ; Olin Corp., McIntosh, AL; and Monsanto Co., Sauget, IL. Throughout 1985, Occidental Chemical Corp.'s Niagara Falls, NY, plant remained temporarily closed. At yearend, 20 mercury-cell chlor-alkali plants were in operation.

Cosan Chemical Corp. of Carlstadt, NJ, became a wholly owned subsidiary of CasChem Group Inc. Reportedly, Cosan is the largest domestic producer of aryl mercury chemicals and the only domestic producer of 100% phenyl mercuric acetate.[7] These products are used as a mildewcide and a preservative in coatings and building products.

Thor Chemicals Inc. in Norwalk, CT, established a warehouse facility for the storage and handling of several different mercury compounds produced at its plants in Natal, Republic of South Africa, and Margate, United Kingdom. The compounds include battery-grade mercurous and mercuric chlorides, urethane and polymerization catalysts, and phenyl mercuric compounds. Thor announced plans to sell and distribute these compounds to consumers in the United States.

### Table 4.—Mercury consumed in the United States, by use

(Flasks)

| SIC code | Use | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|
| 28 | Chemical and allied products: | | | | | |
| 2812 | Chlorine and caustic soda manufacture | 7,323 | 6,243 | 8,054 | 7,347 | 6,700 |
| 2816 | Pigments | W | W | W | W | W |
| 2819 | Catalysts, miscellaneous | 815 | 499 | 484 | 359 | 497 |
| 2821 | Catalysts for plastics | W | W | W | W | W |
| 2819 | Laboratory uses | 328 | 281 | 280 | r269 | 446 |
| 2851 | Paints | 7,949 | 6,794 | 6,047 | 4,651 | 4,892 |
| 2879 | Agricultural chemicals | 79 | 36 | -- | -- | -- |
| -- | Other chemicals and allied products | W | W | W | W | W |
| 36 | Electrical and electronic uses: | | | | | |
| 3641 | Electric lighting | 1,043 | 826 | 1,273 | 1,487 | 1.726 |
| 3643 | Wiring devices and switches | 2,641 | 2,004 | 2,316 | r2,730 | 2,843 |
| 3692 | Batteries | 29,441 | 24,880 | 22,350 | 29,700 | 29,782 |
| -- | Other electrical and electronic uses | W | W | W | W | W |
| 38 | Instruments and related products: | | | | | |
| 382 | Measuring and control instruments | 5,671 | 3,984 | 2,465 | r2,856 | 2,654 |
| 3843 | Dental equipment and supplies | 1,613 | 1,019 | 1,597 | 1,432 | 1,960 |
| -- | Other instruments and related products | 253 | 194 | W | W | W |
| -- | Other | 242 | 984 | 1,356 | 1,404 | 267 |
| | Total | 59,244 | 48,943 | 49,138 | r54,669 | 53,483 |

rRevised. W Withheld to avoid disclosing company proprietary data; included in "Total."

## STOCKS

The NDS, as of December 31, 1985, contained 169,689 flasks of mercury and 80 pounds of mercuric oxide. DOE held 34,720 flasks of secondary mercury in Oak Ridge, TN. Reported stocks of mercury held by mine producers, consumers, and brokers increased during the first half of the year, and thereafter, slowly declined and ended the year at 27,985 flasks.

### Table 5.—Stocks of mercury in the United States, December 31

(Flasks)

| Year | Producer (mine) | Consumer and dealer | Total |
|---|---|---|---|
| 1981 | 11,783 | 15,556 | 27,339 |
| 1982 | 13,598 | 15,229 | 28,827 |
| 1983 | 18,323 | 12,695 | 31,018 |
| 1984r | 19,964 | 7,291 | 27,255 |
| 1985 | 19,398 | 8,587 | 27,985 |

rRevised.

## PRICES

According to Metals Week, the New York dealers' price for mercury was $320 to $325 per flask at the beginning of the year. Thereafter, the price fell until June 7 when it increased to $303 to $310 per flask. On July 18, the price reached a yearly high of $323 to $328 per flask and remained at that level for 15 consecutive weeks owing primarily to a static domestic mercury market. The price then decreased steadily and by yearend reached a yearly low of $273 to $280 per flask.

The London price of mercury (minimum 99.99% pure), quoted by Metal Bulletin (London), reached a high of $300 to $309 per flask for the first 8 days of the year, and thereafter, fell and never regained the $300 level. The price reached a yearly low of $250 to $260 per flask at yearend.

### Table 6.—Average prices of mercury at New York and London

(Per flask)

| Period | New York | London |
|---|---|---|
| 1981 | $413.89 | $417.52 |
| 1982 | 370.93 | 376.96 |
| 1983 | 322.44 | 313.33 |
| 1984 | 314.38 | 306.40 |
| 1985: | | |
| January | 317.52 | 301.66 |
| February | 314.00 | 300.12 |
| March | 309.95 | 296.56 |
| April | 299.59 | 292.88 |
| May | 293.59 | 289.33 |
| June | 310.00 | 291.75 |
| July | 321.46 | 292.83 |
| August | 323.00 | 291.17 |
| September | 323.00 | 288.63 |
| October | 323.00 | 282.22 |
| November | 313.37 | 275.72 |
| December | 283.00 | 259.89 |
| **1985 average** | **310.96** | **288.56** |

Sources: Metals Week (New York) and Metal Bulletin (London).

## FOREIGN TRADE

Imports for consumption of mercury and mercury-bearing waste and scrap, which included imports for immediate consumption plus material withdrawn from bonded warehouses, decreased 25% from the high level in 1984. Spain continued for the third consecutive year to be the leading supplier. The average unit value of imports was $282.53 per flask, compared with $287.20 per flask in 1984.

The U.S. rate of duty on imported mercury and mercury-bearing waste and scrap, TSUS 632.34, as of January 1, 1985, from countries with most-favored-nation status was 6.2 cents per pound.[8] A duty of 25 cents per pound applied to other countries.

### Table 7.—U.S. imports for consumption of mercury and mercury-bearing waste and scrap, by country

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Flasks | Value (thousands) | Flasks | Value (thousands) | Flasks | Value (thousands) |
| Algeria | 1,795 | $560 | 8,201 | $2,441 | 1,938 | $580 |
| Canada | 4 | 19 | 14 | 33 | 5 | 26 |
| China | -- | -- | 350 | 112 | 2,382 | 662 |
| Denmark | -- | -- | 14 | 8 | -- | -- |
| Dominican Republic | 100 | 23 | -- | -- | -- | -- |
| Finland | -- | -- | 120 | 54 | -- | -- |
| France | -- | -- | -- | -- | 1 | 7 |
| Germany, Federal Republic of | 13 | 20 | -- | -- | 500 | 148 |
| Italy | 500 | 122 | 800 | 196 | -- | -- |
| Japan | 511 | 179 | 500 | 120 | 2,502 | 630 |
| Malaysia | -- | -- | -- | -- | 380 | 81 |
| Mexico | 1,590 | 426 | 21 | 9 | 214 | 38 |
| Netherlands | 1,501 | 359 | 1,556 | 392 | -- | -- |
| Spain | 3,408 | 1,063 | 11,749 | 3,344 | 7,955 | 2,322 |
| Turkey | 1,333 | 885 | 2,002 | 564 | 3,012 | 842 |
| United Kingdom | 2,031 | 657 | (1) | 1 | (1) | 1 |
| Total | 12,786 | 3,813 | 25,327 | 7,274 | [2]18,890 | 5,337 |

[1] Less than 1/2 unit.

[2] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

World mine production was 54% of available capacity.

The Bureau of Mines investigated the availability of mercury from 22 deposits in market economy countries.[9] Of the deposits investigated, 15 had demonstrated resources of approximately 25 million metric tons of ore containing 5.3 million flasks of mercury and accounted for 85% of the demonstrated resources for market economy countries. It was concluded that in order to meet anticipated future demand, additional mercury production will be required to supplement those properties currently producing, at higher production costs.

World mercury reserves were estimated by the Bureau of Mines at 4 million flasks, of which 85% is in market economy countries. Spain had the largest share of world reserves, 65%.[10]

**Table 8.—Mercury: World mine production, by country[1]**

(Flasks)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria | 25,000 | 11,000 | [e]10,000 | 23,000 | 25,000 |
| China[e] | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 |
| Czechoslovakia | 4,438 | 4,380 | 4,177 | 4,409 | 4,400 |
| Dominican Republic | 77 | 49 | [e]40 | [e]30 | 20 |
| Finland | 1,949 | [r]2,068 | 1,857 | 2,292 | 2,300 |
| Germany, Federal Republic of | 2,205 | 1,537 | 2,005 | ([2]) | -- |
| Italy | 7,427 | 4,612 | -- | -- | -- |
| Mexico | 6,962 | 8,558 | 6,411 | 11,140 | 10,000 |
| Spain | 46,008 | 48,808 | 41,075 | 44,093 | 45,000 |
| Turkey | [r]5,915 | [r]7,129 | 4,665 | 5,274 | 6,000 |
| U.S.S.R.[e] | 63,000 | 64,000 | 64,000 | 64,000 | 65,000 |
| United States | 27,904 | 25,760 | 25,070 | 19,048 | [3]16,530 |
| Yugoslavia | -- | -- | [e]1,500 | [e]2,000 | 2,000 |
| Total | [r]210,885 | [r]197,901 | 180,800 | 195,286 | 196,250 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through Apr. 22, 1986.

[2] Revised to zero.

[3] Reported figure.

**China.**—Exploration work on the western end of Gongguan-Huilong mercury deposit was reportedly completed with work under way on the eastern end. Ore reserves at the deposit at Dianyang in Shaanxi Province was ranked the second largest in China.[11]

The Songhua River in Northeastern China reportedly has been plagued with mercury emissions from chemical and metallurgical plants. The Government forced an immediate closure of all factories and prohibited all fishing in the area. It was estimated that 150 metric tons of toxic mercury could be present in the banks and body of the river. The Chinese Government in cooperation with Swedish experts was investigating the extent of mercury contamination to the environment.

**Japan.**—In October 1985, the Japanese Ministry of International Trade and Industry (MITI) announced that eight Japanese mercury-cell chlor-alkali producers have until June 30, 1986, to convert to the ion-exchange membrane-cell process in order to comply with its 1983 order. Analysts predicted that the mercury-cell process in Japan will disappear completely by mid-1986.[12]

Several Japanese manufacturers of dry-cell batteries formed the Alkaline Dry Cell Technology Research Association in September 1984 to study ways to reduce the amount of mercury used in dry-cell batteries without reducing their efficiency. The average mercury content in an alkaline-manganese dry-cell battery was 0.33 gram in 1983 and 0.24 gram in 1984. Research and development work was under way during 1985 on a mercury-free alkaline-manganese battery cell. It was reported that a "new material" could appear in the near future to produce the mercury-free battery cell.[13]

**Mexico.**—Four mercury-cell chlor-alkali plants were in operation compared with five in 1984. The producers and locations of the active mercury-cell plants in 1985 were as follows: Guanos y Fertilizantes de México S.A., Salamanca; Pennwalt S.A. de C.V., Santa Clara; Celulosa y Derivados S.A. de C.V., Monterrey; and Industria Química del

Istmo S.A., Pajaritos. The Guanos y Fertilizantes de México's San Cristobal plant did not operate in 1985.[14]

**Spain.**—Three mines in the Almadén region, operated by Minas de Almadén y Arrayanes S.A. (MAYASA), a mining company owned by the Spanish Government, remained the only producers of mercury in Spain. The Almadén Mine, the oldest and richest mercury deposit in the world, is expected to be mined out by the end of the decade. The El Entredicho open pit mine, about 11 miles from Almadén, went into full production in 1982 and since has produced 70% to 80% of the company's output. Reserves, reportedly some of the richest in the world, could last about 25 years at the present production rate. Development work continued at the Las Cuevas Mine, about 5 miles from Almadén. During 1985, small amounts of low-grade waste material were processed. MAYASA estimated the life of this underground mine to be about 20 years and planned to mine it by the vertical crater retreat method.

## TECHNOLOGY

A mercuric iodide crystal was grown in a microgravity environment aboard *Spacelab 3's* shuttle flight in the spring of 1985.[15] The purpose was to grow a near-perfect single crystal of mercuric iodide and to improve the understanding of crystal growth by a vapor process. Mercuric iodide crystals have practical use as sensitive X-ray and gamma-ray detectors and could be useful in portable detector devices for monitoring nuclear powerplants, prospecting for natural resources, biomedical applications in diagnosis and therapy, and in astronomical instruments. In addition to their high-performance electronic properties, these crystals operate well at room temperature. Similar equipment was used on earth to grow an identical crystal under the same environmental conditions other than in microgravity. A comparison of the space- and earth-grown crystals was being made to determine if the microgravity environment was a crucial factor in the growth of a near-perfect single crystal.

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[1] Mineral specialist, Division of Nonferrous Metals.

[2] Flask, as used throughout this chapter, refers to the 76-pound flask.

[3] U.S. Congress. Department of Defense Authorization Act, 1986. Public Law 99-145, Nov. 8, 1985, 99 Stat. 775.

[4] Federal Register. Nonferrous Metals Manufacturing Point Source Category; Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards. V. 50, No. 183, Sept. 20, 1985, pp. 38276-38402.

[5] ———. Water Quality Criteria; Availability of Documents. V. 50, No. 145, July 29, 1985, pp. 30784-30796.

[6] Redistilled mercury is primary mercury further processed or refined to a higher grade.

[7] American Paint and Coatings Journal. CasChem Group Acquires Cosan Chemical Corp. V. 70, No. 16, Oct. 14, 1985, p. 34.

[8] Federal Register. Proclamation of Trade Agreement with Japan and Spain Providing Compensatory Concession. V. 48, No. 247, Dec. 22, 1983, pp. 56553-56559.

[9] Mishra, C. P., D. R. Wilburn, D. G. Hartos, C. D. Sheng-Fogg, and R. C. Bowyer. Mercury Availability—Market Economy Countries. A Minerals Availability Appraisal. BuMines IC 9038, 1985, 18 pp.

[10] Carrico, L. C. Mercury. Ch. in Mineral Facts and Problems, 1985 Edition. BuMines B 675, 1985, p. 500.

[11] Yingbi, D. An Outline of Shaanxi's Mineral Product Resources. Beijing Zhongguo Dizhi (China Geology). No. 8, Aug. 13, 1985, pp. 21-22.

[12] Japan Chemical Week. Caustic Soda Process Conversion Progressing. V. 26, No. 1340, Dec. 5, 1985, p. 1.

[13] ———. Joint Research Assn. Endeavoring for Reduction of Hg Residue in Dry Cell. V. 26, No. 1318, July 4, 1985, p. 7.

[14] The Chlorine Institute Inc. North American Chlor-Alkali Industry Plants and Production Data Book. Pam. 10, Jan. 1986, 20 pp.

[15] Research and Development. Researchers Assess Crystals Grown in Microgravity. V. 27, No. 7, July 1985, pp. 54-55.

# Mica

## By Lawrence L. Davis[1]

In 1985, a total of 138,000 short tons of scrap and flake mica was reported produced in the United States, a 14% decrease from 1984 production.

Nearly all sheet mica supply continued to be imported. Consumption of muscovite mica block decreased by 18% to 51,100 pounds. Consumption of mica splittings remained the same at 2.4 million pounds. The value of sheet mica exports increased 4% to $5.3 million. Imports for consumption of sheet mica increased 14% to 2.7 million pounds.

**Domestic Data Coverage.**—Domestic production and consumption data for mica are developed by the Bureau of Mines by means of three separate, voluntary surveys and one mandatory survey. Of the 63 canvassed operations to which 1 or more of the 4 survey forms were submitted, 56 operations, or 89%, responded. Responses to the scrap and flake mica production form and the ground mica production form were 100%, representing 100% of the totals shown in table 1. Of the eight canvassed operations to which the mica block and film consumption form was sent, seven operations, or 88%, responded, representing 95% of the consumption shown in table 1. Of the 12 canvassed operations to which the mica splittings consumption form was sent, 9 operations, or 75%, responded, representing 90% of the splittings consumption shown in table 1. Consumption for the nonrespondents was estimated using prior year production data.

**Table 1.—Salient mica statistics**

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production (sold or used by producers): | | | | | |
| Scrap and flake mica thousand short tons | 138 | 106 | 140 | 161 | 138 |
| Value thousands | $8,212 | $6,398 | $6,479 | $7,139 | $6,330 |
| Ground mica thousand short tons | 117 | 96 | 130 | 146 | 136 |
| Value thousands | $17,440 | $16,106 | $18,702 | $21,334 | $21,256 |
| Consumption: | | | | | |
| Block, muscovite thousand pounds | 155 | 86 | 74 | 62 | 51 |
| Value thousands | $1,448 | $1,325 | $961 | $842 | $751 |
| Film thousand pounds | W | W | W | W | W |
| Value thousands | W | W | W | W | W |
| Splittings thousand pounds | 4,386 | 2,639 | 2,120 | 2,366 | 2,361 |
| Value thousands | $3,064 | $2,032 | $1,394 | $1,679 | $1,610 |
| Exports thousand short tons | 12 | 12 | 11 | 9 | 10 |
| Imports do | 13 | 10 | 8 | 13 | 11 |
| World: Production thousand pounds | r530,038 | r476,550 | 535,231 | p608,700 | e537,792 |

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.

**Legislation and Government Programs.**—On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. The proposed goals for mica in tier I are 246,400 pounds for muscovite block, 18,700 pounds for muscovite film, 14,391,100 pounds for muscovite splittings, 85,000 pounds for phlogopite block, and 482,600 pounds for phlogopite splittings. Tier II would contain a supplemental reserve of material already possessed by the Government. The proposed goal for tier II is 200,000 pounds of muscovite block. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

The Government inventory of stockpile-grade natural sheet mica was reduced by 3% to 22.4 million pounds by yearend. The General Services Administration sold 800 pounds of muscovite film, 753,000 pounds of muscovite splittings, and 50 pounds of phlogopite splittings.

**Table 2.—Stockpile goals and Government inventories for mica, December 31, 1985**

(Thousand pounds)

| Material | Goal | Inventory: Stockpile grade | Inventory: Non-stock-pile grade | Available for disposal | 1985 sales |
|---|---|---|---|---|---|
| Block: | | | | | |
| Muscovite, Stained and better | 6,200 | 5,006 | 207 | -- | -- |
| Phlogopite | 210 | 17 | 114 | -- | -- |
| Film: Muscovite, 1st and 2d qualities | 90 | 1,178 | 1 | 1,032 | 1 |
| Splittings: | | | | | |
| Muscovite | 12,630 | 14,652 | -- | ([1]) | 753 |
| Phlogopite | 930 | 1,519 | -- | -- | ([1]) |

[1] Less than 1/2 unit.

## DOMESTIC PRODUCTION

**Scrap and Flake Mica.**—U.S. production of scrap (flake) mica[3] was 138,000 tons valued at $6.3 million. North Carolina remained the major producing State with 58% of the total. The remainder was produced in Connecticut, Georgia, New Mexico, Pennsylvania, South Carolina, South Dakota, and Texas. Most of the scrap (flake) mica was recovered from mica schist, high-quality sericite schist, and as a byproduct of kaolin, feldspar, and lithium beneficiation. The five leading producers were, in order of output, Lithium Corp. of America Inc., Gastonia, NC; The Feldspar Corp., Spruce Pine, NC; Mineral Industrial Commodities of America Inc. (M.I.C.A.), Santa Fe, NM; Kings Mountain Mica Co. Inc., Kings Mountain, NC; and Mineral Mining Corp., Kershaw, SC. These five companies produced 61% of the national total.

**Ground Mica.**—Production (sold or used) of ground mica, from scrap and flake mica, decreased 7% to 136,000 tons, valued at $21.3 million. Dry-ground mica, 91% of the total, decreased 8%. The decrease was attributed to decreased demand for mica used in well-drilling muds because of sharply reduced drilling for oil and gas. Wet-ground mica production remained the same. Thirteen companies operated sixteen grinding plants; of these, 12 produced dry-ground and 4 produced wet-ground mica. Leading ground mica producers were, in order of output, U.S.G. Corp., Chicago, IL; Harris Mining Co., Spruce Pine, NC; Pacer Corp., Custer, SD; M.I.C.A, Santa Fe, NM; and Kings Mountain Mica, Kings Mountain, NC. These five companies produced 73% of the national total. Alamo Mining Corp., Van Horn, TX, ceased operations during the year.

**Table 3.—Scrap and flake mica[1] sold or used by producers in the United States, by State**

(Thousand short tons and thousand dollars)

| State | Quantity | Value |
|---|---|---|
| 1981 | 133 | 8,212 |
| 1982 | 106 | 6,398 |
| 1983 | 140 | 6,479 |
| 1984 | 161 | 7,139 |
| 1985: | | |
| North Carolina | 80 | 3,726 |
| Other States[2] | 58 | 2,604 |
| Total | 138 | 6,330 |

[1] Includes finely divided mica recovered from mica schist and high-quality sericite schist, and mica that is a byproduct of feldspar, kaolin, and lithium beneficiation.

[2] Includes Connecticut, Georgia, New Mexico, Pennsylvania, South Carolina, South Dakota, and Texas.

Production of low-quality sericite, primarily for use in brick manufacturing was 41,000 tons valued at $158,000. Approximately 41,000 tons of ground sericite valued at $280,000 was sold or used. Low-quality sericite is excluded from tabulated data contained in this report.

**Table 4.—Ground mica sold or used by producers in the United States, by method of grinding[1]**

(Thousand short tons and thousand dollars)

| Year | Dry-ground | | Wet-ground | | Total[2] | |
|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value |
| 1981 | 107 | 13,439 | 11 | 4,001 | 117 | 17,440 |
| 1982 | 85 | 11,604 | 11 | 4,502 | 96 | 16,106 |
| 1983 | 118 | 13,907 | 12 | 4,795 | 130 | 18,702 |
| 1984 | 133 | 16,269 | 13 | 5,065 | 146 | 21,334 |
| 1985 | 123 | 15,993 | 13 | 5,263 | 136 | 21,256 |

[1] Domestic and some imported scrap. Low-quality sericite is not included.

[2] Data may not add to totals shown because of independent rounding.

## CONSUMPTION AND USES

**Sheet Mica.**—Consumption of muscovite block (ruby and nonruby) totaled 51,100 pounds, a decrease of 18% from that of 1984. Of the total muscovite block fabricated, 81% went into electronic uses; of this, the majority was used in vacuum tubes. Most of the decrease in consumption was in Stained quality, although it remained in greatest demand, accounting for 77% of consumption. Consumption of grade No. 6 increased while consumption of other sizes decreased.

Eight companies continued to consume muscovite block and film in eight plants in seven States; two in North Carolina and one each in Massachusetts, New Jersey, New York, Ohio, Pennsylvania, and Virginia. The New York, Pennsylvania, and Virginia companies consumed 75% of the total.

Phlogopite block fabrication decreased compared with that of 1984. The block was consumed by five companies in five States.

Consumption of mica splittings remained at 2.4 million pounds. Muscovite splittings from India accounted for 99% of the consumption. The remainder was phlogopite splittings from Madagascar. The splittings were fabricated into various built-up mica products by 11 companies operating 11 plants in 9 States.

**Built-up Mica.**—The primary use of this mica-base product, made by mechanical or hand settings of overlapping splittings and alternate layers of binders and splittings, was as electrical insulation material. Total production, sold or used, of built-up mica decreased 4% from that of 1984. Segment plates and molding plates were the major end products, accounting for 31% and 28% of the total, respectively. Other end products included flexible plates, heater plates, and tapes.

**Reconstituted Mica (Mica Paper).**—Five companies consumed 4.9 million pounds of scrap mica to produce 3.3 million pounds of mica paper. The principal source of this scrap mica was India. Primary end uses for mica paper were the same as those for built-up mica. Manufacturing companies were Corona Films Inc., West Townsend, MA; General Electric Co., Schenectady, NY; Kirkwood Acim Corp., Hempstead, NY; WearEver-ProctorSilex, Mt. Airy, NC; and US Samica Corp., Rutland, VT.

**Ground Mica.**—The major end uses were joint cement, 50%; paint, 15%; and well-drilling muds, 12%. Other end uses included plastics, roofing, and rubber.

### Table 5.—Fabrication of muscovite block mica in the United States in 1985, by quality and end product use

(Pounds)

| Quality | Electronic uses | Nonelectronic uses | Total[1] |
|---|---|---|---|
| Good Stained or better | 1,100 | 3,500 | 4,600 |
| Stained | W | W | 39,500 |
| Lower than stained[2] | W | W | 7,000 |
| Total | 41,700 | 9,500 | 51,100 |

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Data may not add to totals shown because of independent rounding.

[2] Includes punch mica.

### Table 6.—Fabrication of muscovite block mica in the United States in 1985, by quality

(Pounds)

| Quality | No. 4 and larger | No. 5 and smaller[1] | Total[2] |
|---|---|---|---|
| Good Stained or better | 3,700 | 1,000 | 4,600 |
| Stained | 6,200 | 33,300 | 39,500 |
| Lower than Stained | 1,400 | 5,600 | 7,000 |
| Total | 11,300 | 39,900 | 51,100 |

[1] Includes all smaller than No. 6 and punch mica.

[2] Data may not add to totals shown because of independent rounding.

### Table 7.—Consumption and stocks of mica splittings in the United States, by source

(Thousand pounds and thousand dollars)

| | India | | Madagascar | | Total[1] | |
|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value |
| Consumption: | | | | | | |
| 1981 | 4,268 | 2,601 | 117 | 463 | 4,386 | 3,064 |
| 1982 | 2,576 | 1,775 | 63 | 257 | 2,639 | 2,032 |
| 1983 | 2,079 | 1,257 | 41 | 137 | 2,120 | 1,394 |
| 1984 | 2,323 | 1,537 | 42 | 141 | 2,366 | 1,679 |
| 1985 | 2,327 | 1,485 | 34 | 125 | 2,361 | 1,610 |
| Stocks on Dec. 31: | | | | | | |
| 1981 | 2,621 | NA | 101 | NA | 2,722 | NA |
| 1982 | 1,922 | NA | 42 | NA | 1,964 | NA |
| 1983 | 1,187 | NA | 148 | NA | 1,335 | NA |
| 1984 | 877 | NA | 77 | NA | 954 | NA |
| 1985 | 1,085 | NA | 41 | NA | 1,126 | NA |

NA Not available.

[1] Data may not add to totals shown because of independent rounding.

### Table 8.—Built-up mica[1] sold or used in the United States, by product

(Thousand pounds and thousand dollars)

| Product | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Flexible (cold) | 237 | 1,072 | 193 | 810 |
| Heater plate | 103 | 397 | 69 | 182 |
| Molding plate | 655 | 1,912 | 654 | 2,397 |
| Segment plate | 773 | 2,651 | 723 | 2,974 |
| Tape | 234 | 1,612 | 266 | 1,675 |
| Other | 404 | 2,155 | 399 | 1,796 |
| Total | 2,406 | 9,799 | 2,304 | [2]9,835 |

[1] Consists of alternate layers of binder and irregularly arranged and partly overlapped splittings.

[2] Data do not add to total shown because of independent rounding.

### Table 9.—Ground mica sold or used by producers in the United States, by end use

(Thousand short tons and thousand dollars)

| End use | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value |
| Joint cement | 68 | 10,193 | 68 | 10,372 |
| Paint | 19 | 3,195 | 20 | 3,451 |
| Plastics | 2 | 427 | 2 | 498 |
| Roofing | W | W | W | W |
| Well-drilling mud | 23 | 2,416 | 16 | 1,730 |
| Other[1] | r34 | r5,102 | 29 | 5,205 |
| Total[2] | 146 | 21,334 | 136 | 21,256 |

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes mica used for agricultural products, molded electrical insulation, rubber, welding rods, textile and decorative coatings, and uses indicated by symbol W.

[2] Data may not add to totals shown because of independent rounding.

## STOCKS

Reported yearend consumer stocks of sheet mica increased 8% to 1.3 million pounds; of this, mica splittings represented 86% and mica block represented 14%.

## PRICES

Average reported values of consumed muscovite sheet mica changed as follows: Block increased 8% to $14.68 per pound; film decreased 30% to $3.79 per pound; and splittings decreased 3% to $0.64 per pound. The average value of phlogopite block increased 104% to $6.90 per pound while the value of phlogopite splittings increased 10% to $3.68 per pound.

The average value of crude scrap (flake) mica, including high-quality sericite, was $46.02 per ton. The average value per ton for North Carolina scrap (flake) mica, predominantly a flotation product, was $46.48.

### Table 10.—Average reported price for dry- and wet-ground mica sold or used by U.S. producers in 1985

(Dollars per short ton)

| Kind | Price |
|---|---|
| Wet-ground | 407 |
| Dry-ground | 130 |
| End uses: |  |
| Joint cement | 152 |
| Paint | 174 |
| Plastics | 218 |
| Roofing | W |
| Well-drilling mud | 106 |
| Other[1] | 182 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes mica used for agricultural products, molded electrical insulation, rubber, welding rods, textile and decorative coatings, miscellaneous, and use indicated by symbol W.

## FOREIGN TRADE

The United States was a net exporter of ground mica in 1985, exporting 14.5 million pounds valued at $2.0 million while importing 12.1 million pounds valued at $2.2 million. Ground mica was exported to 32 countries. The leading countries of destination were Canada, 28%; Mexico, 27%; Venezuela, 10%; and Spain, 7%. Canada supplied 96% of the ground mica imports.

Imports of unmanufactured block, film,

and splittings increased 14% to 1.7 million pounds. It was the first increase since 1980. India remained the primary source, accounting for 98% of the imports.

The total value of exported cut, stamped, and built-up mica was $5.1 million, an increase of 13%. Canada continued to be the leading country of destination, accounting for 31%. Mexico received 25%; Italy, 11%; the United Kingdom, 6%; and the remainder went to 36 countries. The total value of imports of these materials increased 11% to $3.2 million. Of this, 58% by weight and 35% by value was imported from Belgium; 13% by weight and 21% by value came from Japan; and 12% by weight and 31% by value came from India.

The combined value of all mica exports was $7.6 million, an increase of 7%. The total imported mica value was $7.2 million, a 6% increase.

### Table 11.—U.S. exports of mica and manufactures of mica in 1985, by country

(Thousand pounds and thousand dollars)

| Country | Scrap and flake mica | | | | Sheet mica | | |
|---|---|---|---|---|---|---|---|
| | Ground or pulverized | | Waste and scrap[1] | | Unmanufactured block, film, splittings | | Manufactured, cut or stamped, built-up |
| | Quantity | Value | Quantity | Value | Quantity | Value | Value |
| Argentina | 194 | 43 | -- | -- | -- | -- | 14 |
| Australia | 66 | 7 | -- | -- | -- | -- | 212 |
| Bahamas | -- | -- | -- | -- | -- | -- | 36 |
| Belgium | 240 | 23 | -- | -- | -- | -- | 2 |
| Brazil | -- | -- | -- | -- | -- | -- | 295 |
| Canada | 4,024 | 429 | 892 | 121 | -- | -- | 1,569 |
| Colombia | 260 | 46 | 12 | 2 | -- | -- | 40 |
| France | 380 | 36 | -- | -- | -- | -- | 9 |
| Germany, Federal Republic of | 126 | 28 | 80 | 11 | 2 | 11 | 57 |
| India | -- | -- | -- | -- | -- | -- | 106 |
| Italy | 302 | 41 | 160 | 19 | -- | -- | 580 |
| Japan | 734 | 143 | 212 | 35 | 32 | 74 | 34 |
| Korea, Republic of | 484 | 136 | -- | -- | 6 | 17 | 9 |
| Mexico | 3,856 | 496 | 1,562 | 220 | -- | -- | 1,288 |
| Netherlands | 666 | 127 | -- | -- | -- | -- | -- |
| Spain | 1,020 | 139 | -- | -- | 32 | 40 | 287 |
| Sweden | -- | -- | -- | -- | -- | -- | 61 |
| Taiwan | 302 | 30 | -- | -- | -- | -- | 7 |
| United Kingdom | 90 | 10 | -- | -- | 10 | 17 | 319 |
| Venezuela | 1,422 | 160 | -- | -- | -- | -- | 11 |
| Other[2] | 294 | 68 | -- | -- | -- | -- | 167 |
| Total | 14,460 | 1,962 | 2,918 | 408 | 82 | 159 | 5,103 |

[1] Some shipments of ground mica are included in this category.

[2] Includes Barbados, the Cayman Islands, Chile, the Dominican Republic, Ecuador, El Salvador, the French Pacific Islands, Guatemala, Honduras, Hong Kong, Indonesia, Ireland, Israel, Jamaica, Kenya, Malaysia, Mozambique, the Netherlands Antilles, New Zealand, Pakistan, Peru, Philippines, Portugal, Saudi Arabia, Singapore, the Republic of South Africa, Switzerland, Trinidad and Tobago, and Turkey.

Source: Bureau of the Census.

### Table 12.—U.S. imports for consumption of scrap and flake mica, by country

(Thousand pounds and thousand dollars)

| Country | Waste and scrap | | Ground or pulverized | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| 1983 | 3,787 | 316 | 10,304 | 1,873 |
| 1984 | 10,384 | 985 | 12,814 | 2,266 |
| 1985: | | | | |
| Canada | 88 | 3 | 11,666 | 2,077 |
| France | 40 | 11 | -- | -- |
| Germany, Federal Republic of | -- | -- | 4 | 5 |
| India | 7,767 | 689 | 340 | 20 |
| Japan | -- | -- | 87 | 100 |
| Madagascar | 65 | 15 | -- | -- |
| Total | 7,960 | 718 | 12,097 | 2,202 |

Source: Bureau of the Census.

## Table 13.—U.S. imports for consumption of unmanufactured sheet mica, by country

(Thousand pounds and thousand dollars)

| Country | Block | | Splittings | | Not cut or stamped, not over 0.006 inch in thickness[1] | |
|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value |
| 1983 | 44 | 169 | 1,577 | 608 | 278 | 209 |
| 1984 | 68 | 151 | 1,368 | 458 | 44 | 35 |
| 1985: | | | | | | |
| Belgium | -- | -- | 1 | 17 | -- | -- |
| Brazil | 7 | 28 | -- | -- | -- | -- |
| Canada | -- | -- | -- | -- | 5 | 11 |
| France | 9 | 42 | ([2]) | 2 | -- | -- |
| Germany, Federal Republic of | -- | -- | 3 | 3 | -- | -- |
| Gibraltar | -- | -- | 1 | 9 | -- | -- |
| India | 35 | 19 | 1,618 | 926 | -- | -- |
| Japan | 1 | 7 | -- | -- | -- | -- |
| United Kingdom | 2 | 16 | -- | -- | -- | -- |
| Total[3] | 55 | 112 | 1,624 | 957 | 5 | 11 |

[1] Including film.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## Table 14.—U.S. imports for consumption of manufactured sheet mica, by country

(Thousand pounds and thousand dollars)

| Country | Cut or stamped | | | | Plates and built-up | | Articles not especially provided for | |
|---|---|---|---|---|---|---|---|---|
| | Not over 0.006 inch in thickness | | Over 0.006 inch in thickness | | | | | |
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| 1983 | 48 | 633 | 186 | 731 | 460 | 927 | 41 | 292 |
| 1984 | 114 | 517 | 152 | 610 | 467 | 1,007 | 123 | 702 |
| 1985: | | | | | | | | |
| Belgium | -- | -- | -- | -- | 568 | 1,094 | ([1]) | 8 |
| France | -- | -- | -- | -- | 47 | 84 | 29 | 79 |
| Germany, Federal Republic of | -- | -- | -- | -- | -- | -- | 7 | 7 |
| India | 43 | 330 | 52 | 271 | 3 | 14 | 19 | 356 |
| Japan | 16 | 172 | 64 | 251 | 43 | 219 | 8 | 26 |
| Netherlands | -- | -- | ([1]) | 7 | 64 | 111 | ([1]) | 1 |
| United Kingdom | -- | -- | ([1]) | 1 | 2 | 5 | 4 | 33 |
| Other[2] | 1 | 8 | 4 | 30 | 2 | 13 | 3 | 33 |
| Total[3] | 60 | 510 | 120 | 560 | 729 | 1,540 | 69 | 544 |

[1] Less than 1/2 unit.
[2] Includes Canada, China, Haiti, Hong Kong, Italy, Singapore, Spain, Switzerland, and Taiwan.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 15.—Summation of U.S. mica trade data

(Thousand pounds and thousand dollars)

| | Scrap and flake mica | | | | Sheet mica | | | |
|---|---|---|---|---|---|---|---|---|
| | Ground or pulverized | | Waste and scrap[1] | | Unmanufactured block, film, splittings | | Manufactured, cut or stamped, built-up | |
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| Exports: | | | | | | | | |
| 1981 | 13,954 | 2,085 | 7,588 | 1,085 | 298 | 267 | NA | 7,001 |
| 1982 | 16,746 | 2,144 | 5,254 | 742 | 294 | 296 | NA | 5,499 |
| 1983 | 16,430 | 2,112 | 3,986 | 545 | 70 | 109 | NA | 4,001 |
| 1984 | 11,500 | 1,506 | 3,806 | 532 | 348 | 549 | NA | 4,519 |
| 1985 | 14,460 | 1,962 | 2,918 | 408 | 82 | 159 | NA | 5,103 |
| Imports for consumption: | | | | | | | | |
| 1981 | 18,369 | 1,390 | 8,075 | 915 | 3,484 | 1,854 | 688 | 3,377 |
| 1982 | 10,824 | 1,724 | 5,030 | 427 | 3,173 | 1,449 | 724 | 2,936 |
| 1983 | 10,304 | 1,873 | 3,787 | 316 | 1,899 | 986 | 735 | 2,583 |
| 1984 | 12,814 | 2,266 | 10,384 | 985 | 1,480 | 644 | 856 | 2,836 |
| 1985 | 12,097 | 2,202 | 7,960 | 718 | 1,683 | 1,080 | 978 | 3,154 |

NA Not available.

[1] Some shipments of ground mica are included in this category.

Source: Bureau of the Census.

## WORLD REVIEW

World production of mica decreased 12% to 538 million pounds, primarily because of decreased production of scrap and flake mica in the United States. India continued to lead the world in the production of sheet mica. The United States remained the leader in the production of scrap (flake) mica.

**Canada.**—The world's largest known phlogopite deposit and Canada's only commercial mica operation was purchased from Martin Marietta Corp. by Lacana Mining Corp. for about $6.5 million.[3] The purchase includes the deposit and operating mine at Lac Letondal in Suzor Township, Quebec, and a dry processing plant in Boucherville, near Montreal. Lacana is planning to double production over the next 18 to 24 months. Lacana also acquired an option on a muscovite mica deposit from Koizumi Group Canada Ltd. and plans to do some exploration work. The deposit is near Kaladar, Ontario.[4]

**Finland.**—Kemira Oy began operation of its new 22,000-ton-per-year mica processing plant in September. The plant, at Siilinjarvi, uses phlogopite separated by flotation at a nearby apatite plant. Various grades were produced ranging from coarse flakes for use in drilling muds to fine flakes suitable for use in paints, paper, and plastics. The company announced plans to begin operation of a pearlescent pigment plant at its Vuorikemia works in Pori in 1986. The plant will coat mica flakes with titanium dioxide using domestic phlogopite from the Siilinjarvi plant and imported muscovite. Products will be marketed for use in cosmetics, paints, printing inks, and plastics.[5]

**India.**—The Mica Trading Corp. of India Ltd. (MITCO) raised its floor prices for mica powder and flakes by 25%, effective March 1, 1985.[6] MITCO also began a concentrated effort to increase exports of mica to Japan, the Republic of Korea, and Singapore, in a continuing attempt to diversify its export market. All three countries are major importers of mica for use in electronics and electrical products manufacture and are believed to be promising targets for increased Indian export sales.[7]

**Spain.**—Cía. Minera Santa Comba S.A., one of Spain's principal flake mica producers, ceased mica production in 1983.[8] The bulk of the company's production had been exported to the United Kingdom for micronizing.

**United Kingdom.**—Wood Treatment Ltd. doubled its dry grinding plant capacity to about 11,000 tons per year in response to increased demand. Most of the plant feed was crude mica imported from China. A small amount of mica from Brazil was also ground.[9]

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[1] Physical scientist, Division of Industrial Minerals.

[2] Production of high-quality sericite is included in the totals; however, figures for low-quality sericite, used principally for brick manufacturing, are not included.

[3] Mining Journal (London). V. 305, No. 7842, Dec. 6, 1985, p. 433.

[4] Jorgensen, B. Firm Pins Hopes on Mica Being Unseen but Ubiquitous. The Globe and Mail (Toronto), Jan. 10, 1986, p. B13.

[5] Griffith, J. Kemira Mica—Utilizing Resources. Ind. Miner. (London), No. 219, Dec. 1985, pp. 77-83.

[6] Industrial Minerals (London). No. 213, June 1985, p. 10.

[7] ———. No. 214, July 1985, p. 11.

[8] ———. No. 217, Oct. 1985, p. 59.

[9] ———. No. 215, Aug. 1985, p. 15.

## Table 16.—Mica: World production, by country[1]

(Thousand pounds)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina: | | | | | |
| Sheet | 97 | 53 | 62 | 26 | 34 |
| Waste, scrap, etc | 1,012 | 481 | 628 | 613 | 620 |
| Brazil | 1,735 | 1,936 | 7,926 | 7,939 | 7,800 |
| Canada[e] | 24,000 | 22,000 | 23,000 | 23,000 | 25,000 |
| France | 19,972 | 17,527 | 20,472 | 23,929 | 22,000 |
| India: | | | | | |
| Exports: | | | | | |
| Block | 2,610 | [e]2,400 | [e]2,400 | [e]2,400 | 2,200 |
| Film and disk | 768 | [e]440 | [r] [e]440 | [r] [e]440 | 440 |
| Splittings | 7,303 | [e]8,800 | [e]7,000 | [e]7,000 | 7,000 |
| Scrap | 14,274 | [e]17,600 | [e]15,500 | [e]15,500 | 15,500 |
| Powder | 25,674 | [e]11,000 | [e]9,000 | [e]9,000 | 9,000 |
| Manufactured | 925 | [e]660 | [e]1,100 | [e]1,100 | 1,100 |
| Domestic consumption, all forms[e] | 6,600 | 6,600 | 6,600 | 6,600 | 7,700 |
| Total | 58,154 | [e]47,500 | [r] [e]42,040 | [r] [e]42,040 | 42,940 |
| Korea, Republic of (all grades) | [e]22,000 | 44,875 | 31,751 | 53,872 | 33,000 |
| Madagascar (phlogopite) | 844 | 2,866 | 1,585 | 1,587 | 1,500 |
| Mexico (all grades) | 4,579 | 1,124 | 3,439 | 3,695 | 3,500 |
| Morocco | 3,979 | 1,129 | [e]1,100 | 2,646 | 2,600 |
| Mozambique | 660 | 326 | 681 | [e]660 | 660 |
| Namibia | -- | -- | 220 | 198 | -- |
| Peru[e] | 1,265 | 1,200 | 1,200 | 1,200 | 1,200 |
| South Africa, Republic of: | | | | | |
| Sheet | -- | -- | -- | -- | [3]179 |
| Scrap | 5,280 | 3,871 | 5,891 | 9,872 | [3]4,747 |
| Spain | 7,769 | 7,557 | 2,866 | 2,183 | 2,200 |
| Sri Lanka (scrap) | 401 | 642 | 377 | [e]440 | 440 |
| Sudan | 4,409 | 364 | 22 | 22 | 22 |
| Tanzania (sheet) | 11 | 11 | ([4]) | ([4]) | ([4]) |
| Taiwan | 187 | 97 | 686 | 670 | 250 |
| U.S.S.R. (all grades)[e] | 104,000 | 106,000 | 108,000 | 108,000 | 110,000 |
| United States: | | | | | |
| Sheet | NA | NA | NA | NA | NA |
| Scrap and flake[5] | 266,000 | 212,000 | 280,000 | 322,000 | [3]275,100 |
| Yugoslavia | 584 | 3,093 | 2,086 | [r] [e]2,100 | 2,200 |
| Zimbabwe | 3,100 | 1,898 | 1,199 | 2,008 | 1,800 |
| Grand total | [r]530,038 | [r]476,550 | 535,231 | 608,700 | 537,792 |

[e] Estimated. [p] Preliminary. [r] Revised. NA Not available.

[1] Table includes data available through May 13, 1986.

[2] In addition to the countries listed, China, Norway, Pakistan, Romania, and Sweden are known to produce mica, but available information is inadequate to make reliable estimates of output levels.

[3] Reported figure.

[4] Less than 1/2 unit.

[5] Excludes U.S. production of low-quality sericite.

# Molybdenum

## By John W. Blossom[1]

Domestic and foreign molybdenum markets remained imbalanced in 1985. Worldwide mine production exceeded demand, but domestic producer and consumer stocks were kept at a minimum. U.S. mine output of molybdenum increased 4.6% compared with that of 1984 and represented 50% of the world production. Reported end-use consumption of molybdenum in raw materials and apparent domestic demand increased compared with that of 1984. Exports of molybdenum from the United States remained level during 1985. Domestic producer stocks of molybdenum decreased by 5%, but confronted with stock inventories equivalent to about 1 year's consumption, domestic producers' prices were weak. World market prices were below those of most U.S. producer price listings for most of the year.

**Domestic Data Coverage.**—Domestic production data for molybdenum are developed by the Bureau of Mines by means of three separate, voluntary surveys. These surveys are the "Molybdenum Ore and Concentrate," "Molybdenum Concentrate and Molybdenum Products," and "Molybdenum Concentrates." Out of 13 operations to which surveys were sent, all responded, representing 100% of the total production shown in table 1.

**Table 1.—Salient molybdenum statistics**

(Thousand pounds of contained molybdenum and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Concentrate: | | | | | |
| Production | 139,900 | 84,381 | 33,598 | 103,664 | 108,409 |
| Shipments | 118,916 | 76,135 | 48,805 | 102,405 | 111,936 |
| Value | $945,540 | $504,089 | $166,612 | $326,780 | $347,812 |
| Reported consumption | 80,725 | 49,444 | 27,014 | 54,843 | W |
| Imports for consumption | 1,988 | 3,115 | 1,673 | 28 | 112 |
| Stocks, Dec. 31: Mine and plant | 35,043 | 38,510 | 11,637 | 12,450 | 9,322 |
| Primary products: | | | | | |
| Production | 105,824 | 65,381 | 37,533 | 79,689 | 87,436 |
| Shipments | 64,368 | 47,884 | 50,562 | [r] 65,527 | 73,861 |
| Reported consumption | 50,189 | 27,665 | 27,225 | 34,792 | 33,451 |
| Stocks, Dec. 31: Producers | 44,961 | 49,402 | 28,352 | 22,155 | 21,014 |
| World: Mine production | [r]240,003 | [r]209,336 | 140,585 | [p]214,506 | [e]215,139 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

## DOMESTIC PRODUCTION

Domestic mine production of molybdenum increased to a total of 108 million pounds of contained molybdenum, compared with 104 million pounds in 1984. The country's four largest producers were AMAX Inc., Cyprus Minerals Co. (formerly Cyprus Mines Corp.), Duval Corp., and Molycorp Inc., which together produced 87% of the year's total production. Domestic producers attempted to correct oversupply conditions by reducing production.

**Table 2.—Production, shipments, and stocks of molybdenum products in the United States**

(Thousand pounds of contained molybdenum)

| | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 |
|---|---|---|---|---|---|---|
| | Molybdic oxides[1] | | Metal powder | | Ammonium molybdate | |
| Received from other producers | 4,889 | 9,989 | -- | -- | 1,527 | W |
| Gross production during year | 62,131 | 69,978 | 5,863 | 5,416 | 3,332 | W |
| Used to make other products listed here | 21,946 | 21,228 | 1,561 | 1,682 | 2,215 | 1,999 |
| Net production | 40,186 | 48,750 | 4,302 | 3,734 | 1,116 | W |
| Shipments | 50,253 | 58,984 | 4,178 | 3,968 | W | W |
| Producer stocks, Dec. 31 | 17,295 | 16,281 | 594 | W | 684 | W |
| | Sodium molybdate | | Other[2] | | Total | |
| Received from other producers | W | W | 68 | 1,734 | 6,479 | 11,723 |
| Gross production during year | W | W | 8,363 | 12,042 | 79,689 | 87,436 |
| Used to make other products listed here | W | W | 614 | 626 | 26,336 | 25,535 |
| Net production | W | W | 7,749 | 9,417 | 53,353 | 61,901 |
| Shipments | W | W | 11,096 | 10,909 | 65,527 | 73,861 |
| Producer stocks, Dec. 31 | W | W | 3,582 | 4,733 | 22,155 | 21,014 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes technical and purified molybdic oxide and briquets.

[2] Includes ferromolybdenum, calcium molybdate, phosphomolybdic acid, molybdenum disulfide, molybdic acid, molybdenum metal, pellets, molybdenum pentachloride, molybdenum hexacarbonyl, and data indicated by symbol W.

## CONSUMPTION AND USES

The quantity of molybdenum in concentrate roasted domestically to produce technical-grade molybdic oxide increased above that of 1984. The remainder of the mine production of concentrate was either exported for conversion, purified to lubrication-grade molybdenum disulfide, or added to the stocks at mines and plants. The oxide, or roasted concentrate, is the chief form of molybdenum utilized by industry, particularly steel, cast iron, and superalloy producers. However, some of the material is also converted to other molybdenum products, such as ferromolybdenum, high-purity oxide, ammonium and sodium molybdate, and metal powder.

Apparent consumption (defined as U.S. primary plus secondary production plus imports minus exports plus adjustments for Government and industry stock changes) remained about the same, at 42 million pounds of molybdenum. The total reported end-use consumption of molybdenum in raw materials decreased about 4% from that of 1984. Molybdenum consumed in oxide form (technical-grade, purified, and briquets) accounted for about 60% of total reported consumption; in ferromolybdenum, 14%; and in other forms, 26%.

Molybdenum reported as consumed in the production of steel accounted for 57% of total consumption. Approximately 28% of consumption was attributed to other metallurgical uses, such as cast irons, superalloys, and as a refractory metal. Catalyst, lubricant, pigment, and other nonmetallurgical applications composed the final 15% of total consumption. Nearly all end-use areas remained about the same in molybdenum consumption when compared with those of 1984. Notable exceptions were high-strength, low-alloy steel (+46%), tool steel (-41%), cast iron (-36%), and full alloy steel (-12%).

Table 3.—U.S. reported consumption of molybdenum, by end use

(Thousand pounds of contained molybdenum)

| End use | Molybdic oxides | Ferromolybdenum[1] | Ammonium and sodium molybdate | Other molybdenum materials[2] | Total |
|---|---|---|---|---|---|
| 1984 | | | | | |
| Steel: | | | | | |
| Carbon | 787 | 101 | -- | 2 | 890 |
| Stainless and heat resisting | 4,414 | 562 | -- | 154 | 5,130 |
| Full alloy | 8,914 | 835 | -- | 29 | 9,778 |
| High-strength, low-alloy | 1,094 | 531 | -- | 25 | 1,650 |
| Tool | 2,165 | 569 | -- | 27 | 2,761 |
| Cast irons | 407 | 1,208 | -- | 24 | 1,639 |
| Superalloys | 1,230 | 156 | -- | 1,604 | 2,990 |
| Alloys (excludes steels and superalloys): | | | | | |
| Welding and alloy hard-facing rods and materials | -- | 172 | -- | 19 | 191 |
| Other alloys[3] | 282 | 141 | -- | 175 | 598 |
| Mill products made from metal powder | -- | -- | -- | 4,507 | 4,507 |
| Chemicals and ceramics: | | | | | |
| Pigments | W | -- | 302 | -- | 302 |
| Catalysts | 2,601 | W | W | 187 | 2,788 |
| Other | 4 | -- | -- | 835 | 839 |
| Miscellaneous and unspecified | 327 | 87 | 260 | 55 | 729 |
| Total | 22,225 | 4,362 | 562 | 7,643 | 34,792 |
| 1985 | | | | | |
| Steel: | | | | | |
| Carbon | 704 | 138 | -- | -- | 842 |
| Stainless and heat resisting | 4,946 | 627 | -- | 167 | 5,740 |
| Full alloy | 7,773 | 798 | -- | 28 | 8,599 |
| High-strength, low-alloy | 1,342 | 1,075 | -- | W | 2,417 |
| Tool | 1,204 | 418 | -- | W | 1,622 |
| Cast irons | W | 1,049 | -- | W | 1,049 |
| Superalloys | 1,368 | W | -- | 1,788 | 3,156 |
| Alloys (excludes steels and superalloys): | | | | | |
| Welding and alloy hard-facing rods and materials | -- | 168 | -- | W | 168 |
| Other alloys[3] | 200 | 129 | W | 135 | 464 |
| Mill products made from metal powder | -- | -- | -- | 4,621 | 4,621 |
| Chemicals and ceramics: | | | | | |
| Pigments | W | -- | W | -- | W |
| Catalysts | 1,977 | -- | W | 299 | 2,276 |
| Other | 4 | 4 | -- | 732 | 740 |
| Miscellaneous and unspecified | 697 | 144 | 766 | 150 | 1,757 |
| Total | 20,215 | 4,550 | 766 | 7,920 | 33,451 |

W Withheld to avoid disclosing company proprietary data.

[1] Includes calcium molybdate.

[2] Includes purified molybdenum disulfide, molybdenite concentrate added directly to steel, molybdenum metal powder, molybdenum metal, pellets, and other molybdenum materials.

[3] Includes magnetic and nonferrous alloys.

## STOCKS

Total industry stocks, which include those of producers and consumers, decreased by almost 10% to 35 million pounds of contained molybdenum. Inventories of molybdenum in concentrate at mine locations decreased from 12.4 to 9.3 million pounds. Producers' stocks of molybdenum in consumer products, such as oxide, ferromolybdenum, molybdate, metal powders, and other types, decreased from 22 million pounds at the beginning of the year to 21 million pounds by yearend. Compared with monthly molybdenum shipments, yearend producers' stocks of these materials totaled almost a 3.5-month supply. Domestic consumers held inventories of about 4 million pounds throughout most of the year, representing approximately a 1.5-month supply compared with average monthly reported consumption.

### Table 4.—Industry stocks of molybdenum materials, December 31

(Thousand pounds of contained molybdenum)

| Material | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Concentrate: Mine and plant | 35,043 | 38,510 | 11,637 | 12,450 | 9,322 |
| Producers: | | | | | |
| Molybdic oxides[1] | 38,999 | 41,855 | 22,991 | 17,295 | 16,281 |
| Metal powder | 507 | 443 | 503 | 594 | W |
| Ammonium molybdate | 1,075 | 1,072 | 1,038 | 684 | W |
| Sodium molybdate | 27 | 48 | 79 | W | W |
| Other[2] | 4,353 | 5,984 | 3,741 | 3,582 | 4,733 |
| Total | 44,961 | 49,402 | 28,352 | 22,155 | 21,014 |
| Consumers: | | | | | |
| Molybdic oxides[1] | 3,217 | 2,103 | 1,467 | 1,552 | 2,020 |
| Ferromolybdenum[3] | 914 | 616 | 570 | 721 | 597 |
| Ammonium and sodium molybdate | 167 | 76 | 70 | 80 | 47 |
| Other[4] | 1,467 | 1,386 | 1,567 | 1,540 | 1,778 |
| Total | 5,765 | 4,181 | 3,674 | 3,893 | [5]4,441 |
| Grand total | 85,769 | 92,093 | 43,663 | 38,498 | 34,777 |

W Withheld to avoid disclosing company proprietary data.

[1] Includes technical and purified molybdic oxide and briquets.

[2] Includes ferromolybdenum, calcium molybdate, phosphomolybdic acid, molybdenum disulfide, molybdic acid, molybdenum metal, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.

[3] Includes calcium molybdate.

[4] Includes purified molybdenum disulfide, molybdenite concentrate added directly to steel, molybdenum metal powder, molybdenum metal, pellets, and other molybdenum materials.

[5] Data do not add to total shown because of independent rounding.

## PRICES

The price of molybdic oxide (per pound of contained molybdenum) increased from $2.88 in January to $4.43 in March, then declined to the year's low of $2.60 at the end of December. The average price of oxide was $3.33 or $0.23 less than the average price in 1984.

### Table 5.—Domestic price listings for molybdenum

(Per pound)

| | 1984 | 1985 |
|---|---|---|
| Producer quotes: | | |
| Concentrate | $3.36 | $3.18 |
| Ferromolybdenum-export | 4.32 | 3.91 |
| Oxide | 3.56 | 3.33 |

## FOREIGN TRADE

**Exports.**—Exports of molybdenum in concentrate and oxide remained nearly level at about 64 million pounds for 1985. Molybdenum concentrate exports were about 59% of domestic mine production. Approximately 96% of reported concentrate and oxides was shipped to Belgium-Luxembourg, the Federal Republic of Germany, Japan, the Netherlands, and the United Kingdom. The calculated molybdenum content of all exports remained constant at 76 million pounds. Total value of exports decreased from $318 million in 1984 to $316 million in 1985.

**Imports.**—Approximately 5 million pounds of molybdenum in various forms was imported into the United States, a decrease of about 3 million pounds from that in 1984. This quantity represented 12% of apparent consumption. Total value of all forms of molybdenum imported decreased 32% from $38 million in 1984 to $26 million in 1985. In terms of both value and quantity, the major forms imported were as ore and concentrate and as materials in chief value molybdenum. The principal originating countries for these imports were Canada and Chile.

### Table 6.—Molybdenum reported by producers as shipments for export from the United States

(Thousand pounds of contained molybdenum)

| | 1984 | 1985 |
|---|---|---|
| Molybdenite concentrate | 41,687 | 38,646 |
| Molybdic oxide | 24,553 | 36,268 |
| All other primary products | 1,424 | 1,385 |

### Table 7.—U.S. exports of molybdenum ore and concentrates (including roasted concentrates), by country

(Thousand pounds of contained molybdenum and thousand dollars)

| | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value |
| Austria | 2,179 | 8,105 | -- | -- | 31 | 50 |
| Belgium-Luxembourg | 4,354 | 20,171 | 5,146 | 22,629 | 5,743 | 30,114 |
| Brazil | 55 | 246 | 82 | 258 | 153 | 627 |
| Canada | 475 | 1,377 | 281 | 632 | 780 | 1,979 |
| Chile | 1,394 | 1,988 | 208 | 679 | 102 | 377 |
| France | 274 | 593 | -- | -- | -- | -- |
| Germany, Federal Republic of | 6,148 | 20,918 | 6,576 | 14,936 | 3,379 | 7,758 |
| Japan | 4,531 | 17,706 | 6,896 | 25,979 | 7,031 | 26,202 |
| Mexico | 13 | 52 | ([1]) | 1 | 71 | 135 |
| Netherlands | 20,700 | 95,598 | 34,914 | 150,558 | 40,076 | 160,250 |
| Sweden | 1,475 | 3,032 | 789 | 1,674 | 949 | 2,896 |
| United Kingdom | 5,208 | 14,336 | 7,863 | 23,057 | 4,991 | 15,463 |
| Other | 262 | 1,000 | 611 | 2,367 | 552 | 1,840 |
| Total[2] | 47,068 | 185,122 | 63,366 | 242,770 | 63,859 | 247,690 |

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

### Table 8.—U.S. exports of molybdenum products, by country

(Thousand pounds, gross weight, and thousand dollars)

| Product and country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| **Ferromolybdenum:**[1] | | | | |
| Australia | 118 | 240 | 14 | 73 |
| Canada | 37 | 133 | 86 | 285 |
| Japan | -- | -- | 72 | 149 |
| Malaysia | 1 | 4 | -- | -- |
| Mexico | 66 | 169 | 34 | 93 |
| Philippines | ([2]) | 1 | -- | -- |
| South Africa, Republic of | 16 | 50 | -- | -- |
| Other | 411 | 970 | 1,055 | 2,098 |
| Total[3] | 650 | 1,567 | 1,262 | 2,698 |
| **Metal and alloys in crude form and scrap:** | | | | |
| Belgium | 8 | 84 | -- | -- |
| Canada | 57 | 242 | 15 | 114 |
| France | 8 | 80 | 1 | 13 |
| Germany, Federal Republic of | 83 | 96 | 145 | 438 |
| India | -- | -- | 2 | 19 |
| Japan | 30 | 198 | 170 | 700 |
| Mexico | -- | -- | 67 | 174 |
| Netherlands | 61 | 98 | 21 | 206 |
| Spain | 1 | 8 | -- | -- |
| United Kingdom | 53 | 357 | 30 | 265 |
| Other | 5 | 45 | 122 | 436 |
| Total[3] | 306 | 1,209 | 574 | 2,365 |
| **Wire:** | | | | |
| Argentina | 2 | 52 | 8 | 78 |
| Australia | 1 | 9 | -- | -- |
| Bahamas | 78 | 120 | -- | -- |

See footnotes at end of table.

## Table 8.—U.S. exports of molybdenum products, by country —Continued

(Thousand pounds, gross weight, and thousand dollars)

| Product and country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value |
| **Wire —Continued** |  |  |  |  |
| Belgium-Luxembourg | 9 | 188 | 85 | 190 |
| Brazil | 18 | 309 | 21 | 366 |
| Canada | 22 | 514 | 29 | 573 |
| France | 6 | 95 | 2 | 38 |
| Germany, Federal Republic of | 92 | 859 | 119 | 1,470 |
| India | 3 | 47 | 1 | 34 |
| Italy | 26 | 374 | 36 | 449 |
| Japan | 97 | 1,327 | 71 | 1,295 |
| Mexico | 15 | 548 | 11 | 340 |
| Netherlands | 21 | 526 | (2) | 8 |
| Singapore | 1 | 13 | 1 | 8 |
| South Africa, Republic of | (2) | 3 | (2) | 1 |
| Spain | 27 | 326 | 51 | 203 |
| Sweden | 11 | 196 | 15 | 201 |
| United Kingdom | 7 | 100 | 33 | 277 |
| Other | 39 | 400 | 62 | 499 |
| Total[3] | 474 | 5,964 | 546 | 6,130 |
| **Powder:** |  |  |  |  |
| Australia | (2) | 2 | -- | -- |
| Belgium-Luxembourg | -- | -- | (2) | 2 |
| Canada | 4 | 33 | 10 | 106 |
| France | 25 | 362 | 11 | 111 |
| Germany, Federal Republic of | 16 | 73 | 46 | 147 |
| Italy | 2 | 33 | (2) | 6 |
| Japan | 23 | 191 | 45 | 336 |
| Mexico | 37 | 174 | 5 | 60 |
| Netherlands | (2) | 3 | 126 | 477 |
| Sweden | 6 | 39 | -- | -- |
| Taiwan | 148 | 1,668 | 116 | 886 |
| United Kingdom | 11 | 65 | 5 | 47 |
| Other | 189 | 630 | 5 | 124 |
| Total[3] | 461 | 3,272 | 369 | 2,296 |
| **Semifabricated forms, n.e.c.:** |  |  |  |  |
| Australia | 3 | 74 | 2 | 54 |
| Belgium-Luxembourg | 1 | 25 | 7 | 188 |
| Brazil | 31 | 752 | 15 | 420 |
| Canada | 33 | 655 | 13 | 347 |
| France | 13 | 367 | 16 | 681 |
| Germany, Federal Republic of | 36 | 667 | 79 | 1,295 |
| Japan | 41 | 1,074 | 55 | 381 |
| Mexico | 2 | 44 | 3 | 141 |
| Netherlands | 29 | 873 | 34 | 388 |
| Philippines | 1 | 7 | (2) | 4 |
| Singapore | (2) | 12 | (2) | 7 |
| South Africa, Republic of | 1 | 16 | 1 | 81 |
| United Kingdom | 57 | 1,411 | 98 | 2,085 |
| Other | 9 | 390 | 85 | 1,909 |
| Total[3] | 257 | 6,368 | 408 | 8,330 |
| **Molybdenum compounds:** |  |  |  |  |
| Argentina | (2) | 6 | (2) | 3 |
| Australia | 175 | 452 | 274 | 676 |
| Belgium-Luxembourg | 4,688 | 8,346 | 2,755 | 4,797 |
| Brazil | 5 | 26 | 6 | 30 |
| Canada | 513 | 1,937 | 137 | 494 |
| Germany, Federal Republic of | 1,296 | 2,481 | 3,113 | 5,421 |
| Japan | 5,127 | 14,906 | 4,018 | 10,063 |
| Mexico | 7 | 23 | 7 | 76 |
| Netherlands | 6,746 | 13,097 | 6,956 | 12,946 |
| Sweden | 953 | 1,816 | 1,600 | 2,970 |
| Switzerland | 7 | 25 | -- | -- |
| United Kingdom | 2,644 | 5,133 | 3,000 | 5,547 |
| Other | 4,440 | 8,204 | 1,903 | 3,087 |
| Total[3] | 26,602 | 56,453 | 23,769 | 46,169 |

[1] Ferromolybdenum contains about 60% to 65% molybdenum.

[2] Less than 1/2 unit.

[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

### Table 9.—U.S. imports for consumption of molybdenum

(Thousand pounds and thousand dollars)

| Item | TSUS No. | 1984 |  |  | 1985 |  |  |
|---|---|---|---|---|---|---|---|
|  |  | Gross weight | Contained molybdenum | Value | Gross weight | Contained molybdenum | Value |
| Ore and concentrate | 601.33 | 46 | 28 | 183 | 182 | 112 | 566 |
| Material in chief value molybdenum | 603.40 | 8,800 | 5,266 | 19,441 | 4,173 | 2,239 | 7,329 |
| Ferromolybdenum | 606.31 | 2,086 | 1,545 | 4,438 | 1,424 | 945 | 3,721 |
| Waste and scrap | 628.70 | NA | 437 | 2,565 | NA | 517 | 2,830 |
| Unwrought | 628.72 | NA | 142 | 2,170 | NA | 145 | 2,370 |
| Wrought | 628.74 | 132 | NA | 3,023 | 94 | NA | 2,301 |
| Ammonium molybdate | 417.28 | 95 | 54 | 287 | 386 | 223 | 1,028 |
| Molybdenum compounds | 419.60 | 883 | 599 | 2,547 | 872 | 578 | 2,563 |
| Sodium molybdate | 421.10 | 183 | 108 | 319 | 365 | 205 | 721 |
| Mixtures of inorganic compounds, chief value molybdenum | 423.88 | 250 | 42 | 731 | 38 | 7 | 88 |
| Molybdenum orange | 473.18 | 2,026 | NA | 2,367 | 2,154 | NA | 2,278 |
| Total[1] |  | 14,501 | 8,221 | 38,071 | 9,686 | 4,969 | 25,794 |

NA Not available.

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

### Table 10.—U.S. import duties on molybdenum

| Item | TSUS No. | Most favored nation (MFN) |  | Non-MFN |
|---|---|---|---|---|
|  |  | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Molybdenum ore and concentrate | 601.33 | 9.8 cents per pound | 9 cents per pound | 35 cents per pound. |
| Material in chief value molybdenum | 603.40 | 7 cents per pound plus 2.2% ad valorem. | 6 cents per pound plus 1.9% ad valorem. | 50 cents per pound plus 15% ad valorem. |
| Ferromolybdenum | 606.31 | 5.2% ad valorem | 4.5% ad valorem | 31.5% ad valorem. |
| Molybdenum: |  |  |  |  |
| Waste and scrap | 628.70 | 7.1% ad valorem | 6% ad valorem | 50% ad valorem. |
| Unwrought | 628.72 | 7.2 cents per pound plus 2.2% ad valorem. | 6.3 cents per pound plus 1.9% ad valorem. | 50 cents per pound plus 15% ad valorem. |
| Wrought | 628.74 | 8.1% ad valorem | 6.6% ad valorem | 60% ad valorem. |
| Molybdenum chemicals: |  |  |  |  |
| Ammonium molybdate | 417.28 | 4.8% ad valorem | 4.3% ad valorem | 29% ad valorem. |
| Calcium molybdate | 418.26 | do | 4.7% ad valorem | 24.5% ad valorem. |
| Molybdenum compounds | 419.60 | 3.4% ad valorem | 3.2% ad valorem | 20.5% ad valorem. |
| Potassium molybdate | 420.22 | 3.2% ad valorem | 3% ad valorem | 23% ad valorem. |
| Sodium molybdate | 421.10 | 4.1% ad valorem | 3.7% ad valorem | 25.5% ad valorem. |
| Mixtures of inorganic compounds, chief value molybdenum | 423.88 | 3% ad valorem | 2.8% ad valorem | 18% ad valorem. |
| Molybdenum orange | 473.18 | 4% ad valorem | 3.7% ad valorem | 25% ad valorem. |

## WORLD REVIEW

World mine production of molybdenum was 215 million pounds, about the same production as that of 1984. Canada, Chile, the U.S.S.R., and the United States accounted for more than 89% of the molybdenum produced worldwide. Although comprehensive statistics on world consumption were not available, market evidence clearly indicated that supply exceeded demand. World molybdenum consumption remained level, and stocks continued to decrease but exceeded more than 1 year's demand.

**Canada.**—Molybdenum production (shipments) in Canada decreased by about 32% in 1985 from that in 1984.

Brenda Mines Ltd. restarted production on September 15 following an agreement reached with the Commission of Critical Industries of British Columbia.

Lornex Mining Corp. Ltd.'s copper-molybdenum mine returned to profitability after 1 year of operating at a loss. Output of molybdenum at the Highland Valley Mine increased 14% during 1985.

**Chile.**—Molybdenum production from Corporación Nacional del Cobre de Chile (CODELCO-Chile) increased 9% compared with that of 1984. Much of CODELCO-Chile's production came from the Chuquicamata Mine, the largest copper mine in the world.

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[1] Physical scientist, Division of Ferrous Metals.

**Table 11.—Molybdenum: World mine production, by country[1]**

(Thousand pounds of contained molybdenum)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Bulgaria[e] | 330 | [r]375 | [r]420 | [r]420 | 420 |
| Canada (shipments) | [r]28,329 | [r]30,779 | 22,474 | 25,479 | 16,730 |
| Chile | 33,863 | 44,198 | 33,651 | 37,172 | [3]40,543 |
| China[e] | 4,400 | 4,400 | 4,400 | 4,400 | 4,400 |
| Japan[e] | 163 | 214 | 214 | [r]324 | 215 |
| Korea, Republic of | 1,023 | 796 | 318 | 348 | 660 |
| Mexico | 994 | 11,442 | 12,932 | 8,938 | 8,150 |
| Mongolia[e] | 1,460 | 1,830 | 2,120 | 2,200 | 2,200 |
| Niger | 249 | 93 | [e]88 | [e]73 | 73 |
| Peru | 5,485 | 6,378 | 5,794 | 6,788 | [3]8,439 |
| Philippines | 207 | 150 | 86 | -- | -- |
| U.S.S.R.[e] | 23,600 | 24,300 | [r]24,500 | 24,700 | 24,900 |
| United States | 139,900 | 84,381 | 33,593 | 103,664 | [3]108,409 |
| Total | [r]240,003 | [r]209,336 | 140,585 | 214,506 | 215,139 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through June 17, 1986.

[2] In addition to the countries listed, North Korea, Romania, Turkey, and Yugoslavia are believed to produce molybdenum, but output is not reported quantitatively, and available general information is inadequate to make reliable estimates of output levels.

[3] Reported figure.

# Nickel

## By Peter G. Chamberlain[1]

Calculated apparent nickel demand in the United States was about the same as that of 1984. However, reported consumption of nickel in stainless and heat-resistant steels, alloy steels, copper-nickel alloys, and other nickel-based alloys decreased. Superalloys and miscellaneous uses provided the only major gains in consumption. In addition to being an important constituent of stainless steel, nickel formed a critical component of essential alloys in electronics, aerospace, and other applications. Consequently, nickel production, consumption, and trade impacted these major industrial sectors.

Worldwide, the nickel production in 1985 continued to rebound from its 1982 low. World demand did not keep pace, however,

**Table 1.—Salient nickel statistics**

(Short tons of contained nickel unless otherwise specified)

|  | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: |  |  |  |  |  |
| Mine production: |  |  |  |  |  |
| Nickel ore (gross weight) | 1,794,000 | 432,488 | -- | 1,674,600 | 868,100 |
| Shipments | 12,099 | 3,203 | -- | 14,540 | 6,127 |
| Plant production: |  |  |  |  |  |
| Smelter, from domestic ores (includes byproduct nickel) | 10,305 | 3,456 | W | 9,604 | 5,214 |
| Refinery, from imported matte | 38,500 | 41,500 | 33,400 | 35,329 | 31,168 |
| Secondary recovery, from purchased scrap:[e] |  |  |  |  |  |
| From ferrous scrap | 34,459 | 30,034 | 30,076 | [r]35,760 | [p]41,151 |
| From nonferrous scrap | 17,617 | 12,934 | 19,776 | [r]19,407 | 16,032 |
| Exports: |  |  |  |  |  |
| Primary (unwrought) | 19,674 | 37,356 | 23,359 | [r]31,638 | 21,745 |
| Total (gross weight) | 46,836 | 57,029 | 43,913 | [r]58,525 | 51,429 |
| Imports for consumption: |  |  |  |  |  |
| Primary | 209,008 | 129,787 | 152,333 | 176,715 | 157,690 |
| Primary (gross weight) | 306,747 | 177,493 | 215,361 | 249,929 | 220,349 |
| Total (gross weight) | 315,837 | 186,913 | 225,537 | 264,778 | 236,001 |
| Consumption: |  |  |  |  |  |
| Reported: |  |  |  |  |  |
| Primary | 144,851 | 103,981 | 127,845 | 136,861 | 119,907 |
| Secondary (purchased scrap)[e] | 43,768 | 35,690 | 42,034 | 49,649 | [p]43,903 |
| Apparent: |  |  |  |  |  |
| Primary | 153,994 | 138,032 | [r]154,148 | [r]155,395 | 161,973 |
| Secondary (purchased scrap)[e] | 52,076 | 42,968 | 49,852 | [r]55,167 | [p]57,183 |
| Stocks, yearend: |  |  |  |  |  |
| Producer | 100,000 | 62,000 | 38,500 | 37,300 | 13,300 |
| Consumer: |  |  |  |  |  |
| Primary | 22,508 | 18,853 | 20,448 | 20,934 | 19,106 |
| Secondary[e] | 11,326 | 10,004 | 10,304 | 6,520 | [p]6,320 |
| Employment, yearend: |  |  |  |  |  |
| Mine | 160 | 160 | 160 | 130 | 130 |
| Smelter | 230 | 230 | 230 | 170 | 170 |
| Refinery | NA | 420 | 420 | 420 | -- |
| Price (cathode):[1] |  |  |  |  |  |
| Producer (North American), per pound | $3.43 | $3.20 | XX | XX | XX |
| New York dealer, per pound | $2.65 | $2.24 | $2.20 | $2.22 | $2.26 |
| World: Mine production | [r]800,032 | [r]681,715 | 735,359 | [p]832,592 | [e]856,749 |

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1] Weighted average calculated by Metals Week.

sustaining a serious oversupply. World mine capacity continued to exceed production by 25%.

Concerns over short-term nickel supplies pushed the nickel price upwards during the first half of the year. However, the excess supply situation that developed in the second half of the year drove the price down to its lowest level since early 1983.

The major event affecting the domestic nickel producers was the closure of AMAX Nickel Inc.'s Port Nickel refinery in Braithwaite, LA. The refinery was the country's only primary nickel-cobalt refinery. The M.A. Hanna Co., formerly Hanna Mining Co., temporarily closed its integrated nickel mine and smelter at midyear to install a wet screening unit at the mine and a slurry transportation system to haul the ore to the smelter.

**Domestic Data Coverage.**—Domestic primary production data for nickel are obtained by the Bureau of Mines from a survey of the single integrated nickel mine-smelter and from another survey of the two copper refineries that produced byproduct nickel. Domestic consumption data for nickel are developed by the Bureau from a voluntary survey of U.S. operations. Of the 375 operations to which a survey request was sent, 340 responded, representing 74% of the apparent primary nickel consumption shown in table 4. Apparent consumption of primary nickel was estimated using U.S. primary production plus imports minus exports plus adjustments for Government and industry stock changes.

**Legislation and Government Programs.**—The General Services Administration (GSA) received 5,014 short tons of vacuum-melting-grade nickel for the National Defense Stockpile. The material, purchased in late 1984, brought the yearend inventory to 37,223 tons, well below the goal of 200,000 tons.

On July 8, the President approved recommendations by the National Security Council (NSC) for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict that would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, nickel would be categorized in tier II, and the goal would be 5,000 tons. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

The U.S. Department of the Treasury, Bureau of the Mint, solicited bids on March 8, 1985, for copper-nickel coin blanks instead of the raw metal usually purchased. The purpose was to cut fabrication costs and shift expenses from normal operating funds to the special Mint coinage fund. Concerns raised by domestic mills and members of Congress that foreign bidders would have a built-in cost advantage convinced the Mint, however, not to award any contracts under the solicitation. Arrowhead Metals Ltd., Toronto, Canada—the lowest bidder—unsuccessfully challenged the decision to drop the solicitation in Federal courts. Meanwhile, the Mint purchased 1,700 tons of nickel under three tenders for processing into coins according to the past practices. Most was purchased from trading companies with U.S. offices; AMAX Nickel provided 263 tons as one of its last sales before ceasing primary nickel production.

U.S. Geological Survey (USGS) continued exploring and evaluating the Exclusive Economic Zone for seafloor mineral resources, particularly cobalt-nickel-manganese crusts. The U.S. Department of the Interior's Minerals Management Service (MMS) established a new office, the Office of Strategic and International Minerals, to formulate policies for exploring and developing minerals from the Outer Continental Shelf. An interagency working group consisting of the USGS, National Oceanic and Atmospheric Administration, and MMS completed draft regulations on such activities. MMS financed detailed geologic and hydrothermal studies of the Gorda Ridge crust deposit off the Oregon coast. The Gorda Ridge Technical Task Force, consisting of State and Federal representatives, formulated recommendations to the Secretary of the Interior regarding future leasing.

Possible seafloor mineral development moved closer to reality near Hawaii as the Hawaiian Task Force reviewed mine development scenarios, developed leasing plans, and began overseeing an Environmental Impact Statement (EIS). MMS sponsored an additional data-gathering cruise over the Cross Seamounts site, one of the most promising crust deposits near Hawaii.

Congress failed to enact legislation reauthorizing the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund) prior to its expiration on September 30. Moreover, no Superfund legislation passed by yearend. Money from the Superfund is critical to maintaining the Environmental Protection Agency's hazardous waste cleanup program.

The President signed legislation, Senate bill 883, into law in July. The law extended the Export Administration Act, which restricts exports of many nickel and cobalt strategic alloys. Although the act's Commodity Control List remained unchanged, export licensing regulations were loosened for trade with countries that are members of the Free World Coordinating Committee of Western Trading Partners. The extension also restricted the President's ability to block existing export contracts for political purposes.

## DOMESTIC PRODUCTION

Hanna closed its mine and ferronickel smelter at Riddle, OR, on June 15 for construction of a wet screening system at the mine. The system is expected to concentrate the ore by a factor of two with attendant savings in haulage and roasting costs. A new ore transportation system was also installed during the $13 million capital improvement program. Prior to undertaking the modifications, Hanna received a 5-year extension to the reduced-power-rate agreement with the Bonneville Power Administration. The company also negotiated a 5-year labor contract with the union before committing funds to improvements. Although the mine reopened in October, most activity was devoted to fine-tuning the new systems. Hanna had not refired its smelter furnaces by yearend. Consequently, U.S. mine and smelter production in 1985 was one-half that of 1984.

AMAX Nickel closed its Port Nickel refinery in Braithwaite, LA, on November 30. This action left the Nation with no primary nickel or cobalt refining capacity. During events culminating in the closure, AMAX Nickel released Bamangwato Concessions Ltd. (BCL) of Botswana from its contract to supply AMAX Nickel with nickel matte for the refinery. AMAX Nickel also contracted to resell the matte that it purchased from Agnew Mining Co. Pty. Ltd., Australia, to Sherritt Gordon Mines Ltd., Canada, and Outokumpu Oy, Finland. The refinery had received about 60% of its matte feedstock from BCL and 40% from Agnew. The closure dropped domestic refinery production 12% from that of 1984.

The U.S. Forest Service informed California Nickel Corp., the U.S. exploration and mining subsidiary of Ni-Cal Development Ltd., that additional information was needed for the EIS on a proposed nickel bulk sampling operation at Gasquet Mountain. The administrative order rescinded the Forest Service District's tentative approval of California Nickel's operating plan. The company conducted additional studies on tailing characteristics to fulfill the additional requirements pursuant to the order.

Ni-Cal Technology Ltd., another subsidiary of Ni-Cal Development, received permission from the Del Norte County Planning Commission in California to construct a research laboratory and an 85-ton-per-day demonstration plant near Smith River, CA. Ni-Cal Technology intended to test its acid leaching process, developed for the Gasquet Mountain deposit, at the facility preparatory to world marketing efforts. Environmental groups brought court action against the commission, however, to block the approval. When the court judgment imposed additional environmental data-gathering requirements on the company as a prerequisite for approval, Ni-Cal Technology dropped the pilot plant from further consideration.

Davy McKee Corp. completed its preliminary assessment of the Pine Flat nickel laterite deposit in northern California for Interstrat Resources Inc. The favorable assessment spawned a full engineering and cost study, initiated in November, on the feasibility of producing nickel, chromium, cobalt, and magnesium from the site. A sulfuric acid leaching system was contemplated.

In contrast to the minor domestic production of primary nickel, the production of domestic secondary nickel in the form of scrap recovery was a major source of nickel for many consumers. Since the Bureau of Mines documents only the recovery of nickel in scrap that is consumed, recovery and consumption figures are essentially the same. Recovery of nickel in scrap increased, reflecting the availability of low-cost stainless steel scrap, the major scrap form. The nickel recovered from scrap stainless steel was calculated from the gross weight of the scrap and an estimated nickel content of 6%, which is the weighted-average content in all stainless steels produced since 1962.

Table 2.—Nickel recovered from purchased scrap in the United States, by kind of scrap and form of recovery[e]

(Short tons of contained nickel)

| | 1984[r] | 1985 |
|---|---|---|
| KIND OF SCRAP | | |
| Aluminum-base | 2,449 | 121 |
| Copper-base | 3,500 | 2,503 |
| Ferrous-base | 35,760 | [p]41,151 |
| Nickel-base | 13,458 | 13,408 |
| Total | 55,167 | [p]57,183 |
| FORM OF RECOVERY | | |
| Aluminum-base alloys | 2,547 | 118 |
| Chemical compounds | 391 | -- |
| Copper-base alloys | 7,938 | 10,635 |
| Ferrous alloys | 36,855 | [p]41,283 |
| Metal | -- | -- |
| Nickel-base alloys | 7,436 | 5,147 |
| Total | 55,167 | [p]57,183 |

[e] Estimated. [p] Preliminary. [r] Revised.

## CONSUMPTION

Reported domestic primary nickel consumption decreased considerably from that of 1984. Consumption shrank in stainless and heat-resistant steels, alloy steels, copper-nickel alloys, and other nickel-based alloys. Nickel consumption gained appreciably only in superalloys and miscellaneous uses; in electroplating, it remained essentially unchanged. Despite the drop in reported consumption, the apparent primary consumption changed only slightly from that of 1984. The market was lethargic despite gains in such economic indicators as the gross national product, consumer purchases of durable goods, and construction spending. Clearly, factors in addition to the general economic health controlled nickel demand. The resultant diminishing "intensity of use" pervaded essentially all major nickel consuming industries.[3] Other materials, particularly plastics, continued to be preferred over nickel in finished products used in nonstressful environments. A ubiquitous trend toward lightness and economy fostered these substitutions. Imports of nickel alloys and fabricated products containing such alloys also decreased domestic consumption of primary nickel.

Commercially pure unwrought nickel (Class I) in the form of electrolytic cathodes, pellets, briquets, or powder again dominated the forms of primary nickel consumed. These forms comprised most of the nickel consumed in all products except in stainless and heat-resistant steels wherein they were a major but not dominant nickel source. Cathodes and pellets comprised 73% of the pure unwrought nickel. The Class II materials—ferronickel, nickel oxide, oxide sinter, and utility-grade nickel—were primarily used in producing stainless and heat-resistant steels.

Consumption of nickel in scrap was a major form of consumption in stainless steel production. Since the value of stainless steel scrap was generally less than the value of the sum of its primary components (nickel, chromium, and iron), steelmakers charged furnaces with as much scrap as was available. The nickel consumed as outside scrap (old and new scrap received by the consumer from outside sources, generally through purchases) contributed an estimated 40% of the total nickel consumed in producing stainless steel, about the same as that of 1984. Consumption statistics include only this outside scrap to avoid double counting.

The use of scrap nickel in producing nonferrous alloys remained constant at about one-fourth of the nickel consumed in those alloys. About one-half of nickel in cast iron originated as outside scrap. For chemicals, essentially none of the nickel was secondary. For steel alloys, excluding stainless and heat-resistant steels, less than 10% of the nickel consumed was consumed in the form of outside scrap.

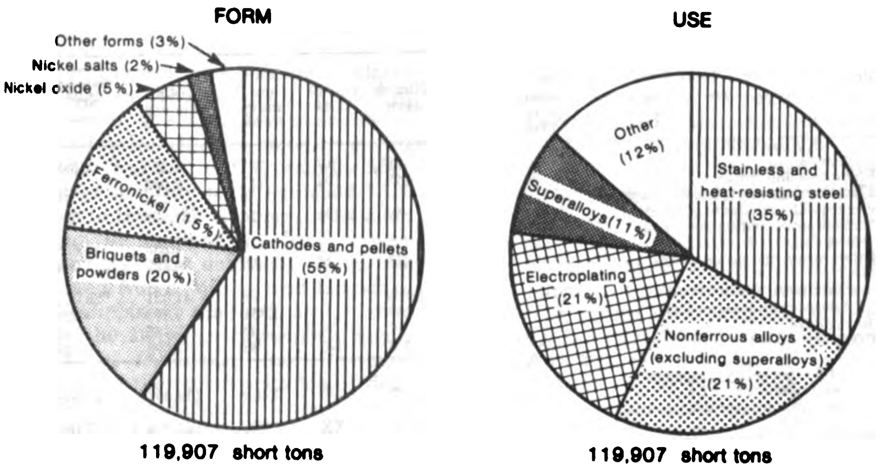

Figure 1.—U.S. nickel consumption in 1985, by form and use.

### Table 3.—U.S. consumption of nickel,[1] by form

(Short tons of contained nickel)

| Form | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Primary: | | | | | |
| Ferronickel | 26,290 | 15,426 | 15,595 | 18,419 | 17,993 |
| Metal | 101,847 | 79,032 | 96,981 | 104,958 | 90,379 |
| Oxide powder and oxide sinter | 9,412 | 4,196 | 9,670 | 7,087 | 6,297 |
| Salts[2] | 4,197 | 3,874 | 4,402 | 2,962 | 2,770 |
| Other | 3,105 | 1,453 | 1,197 | 3,435 | 2,468 |
| Total primary | 144,851 | 103,981 | 127,845 | 136,861 | 119,907 |
| Secondary (scrap)[3] | 43,768 | 35,690 | 42,034 | 49,649 | [P]43,903 |
| Grand total | 188,619 | 139,671 | 169,879 | 186,510 | 163,810 |

[P] Preliminary.
[1] Reported.
[2] Metallic nickel salts consumed by plating industry are estimated.
[3] Based on gross weight of purchased scrap consumed and estimated average nickel content.

### Table 4.—U.S. consumption of nickel in 1985, by use

(Short tons of contained nickel)

| Use | Commercially pure nickel | Ferronickel | Nickel oxide | Nickel salts | Other primary forms | Total primary | Secondary[e] (scrap) | Grand total |
|---|---|---|---|---|---|---|---|---|
| Cast irons | 729 | 356 | 98 | W | 337 | 1,520 | 1,588 | 3,108 |
| Chemicals and chemical uses | 1,580 | -- | 223 | 104 | 147 | 2,054 | -- | 2,054 |
| Electric, magnet, expansion alloys | 733 | -- | -- | -- | 1 | 734 | 70 | 804 |
| Electroplating (sales to platers)[1] | 22,354 | W | W | 2,496 | 18 | 24,868 | -- | 24,868 |
| Nickel-copper and copper-nickel alloys | 3,895 | -- | 9 | -- | 329 | 4,233 | 10,635 | 14,868 |
| Other nickel and nickel alloys | 19,454 | 388 | 255 | 27 | 66 | 20,190 | 5,082 | 25,272 |
| Steel: | | | | | | | | |
| Stainless and heat-resistant | 20,811 | 15,847 | 5,185 | -- | 78 | 41,921 | [p]26,055 | 67,976 |
| Alloys (excludes stainless) | 6,458 | 1,235 | 269 | -- | 1,351 | 9,313 | [p]290 | 9,603 |
| Superalloys | 13,361 | W | W | W | 105 | 13,466 | 148 | 13,614 |
| Other[2] | 1,004 | 167 | 258 | 143 | 36 | 1,608 | 35 | 1,643 |
| Total reported by companies canvassed | 90,379 | 17,993 | 6,297 | 2,770 | 2,468 | 119,907 | 43,903 | 163,810 |
| Total all companies, apparent primary | XX | XX | XX | XX | XX | [3]161,973 | [p]57,183 | 219,156 |

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data; included with "Other."
XX Not applicable.

[1] Based on monthly estimates.

[2] Includes batteries, ceramics, and other alloys containing nickel.

[3] U.S. production plus imports minus exports minus stock increases.

## STOCKS

The combined stocks of primary nickel maintained in the United States by U.S. producers, foreign producers with U.S. sales offices, and metal trading companies with U.S. sales offices decreased sharply during the year. At yearend, these stocks represented slightly over 1 month's domestic consumption. Much of the drop was attributed to the closure of AMAX Nickel's refinery and the attendant liquidation of its inventory.

Nickel stocks on the London Metal Exchange (LME) remained fairly constant after their big decrease in 1984. The yearend inventory was about 7,100 tons compared with 8,100 tons at yearend 1984.

Consumer stocks declined steadily throughout the year. In December, a buying surge by a few companies, however, swelled the yearend inventory to nearly the same amount as at yearend 1984. Although consumer stocks averaged about 1 month's domestic consumption, the yearend level reached about 6 weeks' consumption. Stocks of nickel in ferrous scrap held by iron and steel producers were about the same at yearend as they were at yearend 1984.

GSA received 5,014 tons of vacuum-melting-grade nickel, purchased in 1984, for the National Defense Stockpile. This raised the total nickel stocks to 37,223 tons, considerably less than the 200,000-ton goal.

### Table 5.—Nickel in consumer stocks in the United States, by form

(Short tons of contained nickel)

| Form | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Primary: | | | | | |
| Ferronickel | 2,257 | 1,122 | 893 | 692 | 1,930 |
| Metal | 18,355 | 16,743 | 17,359 | 17,479 | 13,754 |
| Oxide and oxide sinter | 1,039 | 488 | 1,677 | 2,259 | 3,059 |
| Salts | 508 | 226 | 268 | 229 | 184 |
| Other | 349 | 274 | 251 | 275 | 179 |
| Total primary | 22,508 | 18,853 | 20,448 | 20,934 | 19,106 |
| Secondary (scrap) | 11,326 | 10,004 | 10,304 | 6,520 | [p]6,320 |
| Grand total | 33,834 | 28,857 | 30,752 | [r]27,454 | 25,426 |

[p]Preliminary. [r]Revised.

## PRICES

The world nickel price was more volatile than it was in 1983 and 1984. Fueled by concerns over the short-range supply of nickel, the price climbed steadily during most of the first half of the year. By May, the average monthly price exceeded $2.50 per pound in the LME compared with $2.24 per pound in January. In June, however, supply concerns dissipated when the U.S.S.R. and Nonoc Mining and Industrial Corp., Philippines, renewed nickel shipments to the LME. In September, heavy shipments of ferronickel into European markets drove the nickel price lower, demonstrating the existence of a considerable oversupply of the material. The collapse of the International Tin Council's buffer stock acquisition program in October further lowered the price amid concerns over the future trading of all base metals. The LME price eventually hit a 3-year low of $1.77 per pound before recovering at yearend. The weighted-average LME price for 1985 was $2.258 per pound for prompt delivery.[3]

In the United States, the New York dealer selling price for electrolytic cathode nickel best indicated prices paid by domestic consumers. At a weighted-annual average of $2.26 per pound, it closely paralleled the LME price. An overabundance of ferronickel kept its price lower than the cathode and briquet price despite the contained iron credits. Although the producer list prices remained about $3.20 per pound, major producers discounted nickel prices to levels that yielded 10 to 15 cents per pound more than the LME price. One producer, for instance, realized an average of $2.39 per pound for its nickel over the year.

## FOREIGN TRADE

Since the U.S. net import reliance for nickel was 72%, nickel imports dominated trade statistics. Nickel originating from Canada comprised the major import tonnage, especially considering that most of the nickel imported from Norway was mined and smelted in Canada before being shipped to Kristiansand, Norway, for refining. Imports from Australia and Botswana remained important because nickel matte purchased from sources in those countries supplied AMAX Nickel's Port Nickel refinery in Louisiana until it closed in November.

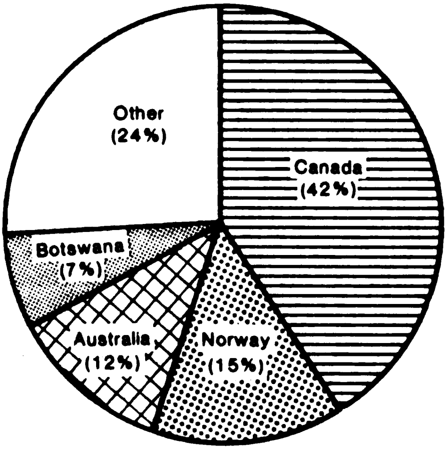

Figure 2.—Major sources of U.S. primary nickel imports in 1985.

An international advisory panel to the General Agreement on Tariffs and Trade (GATT) recommended that voluntary restraint agreements should be brought into conformance with GATT rules. The panel, which included a U.S. representative, concluded that trade agreements such as that of steel between the United States and the European Economic Community, as well as the U.S. import restraints negotiated with Japanese automakers, violate the free trade principles agreed upon by GATT signatory nations. The recommendations reportedly may lead to a revamping of GATT.

### Table 6.—U.S. exports of nickel and nickel alloy products, by class

(Gross weight unless otherwise specified)

| Class | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Primary: | | | | | | |
| Cathodes, pellets, briquets (unwrought) | 22,165 | $99,097 | 25,997 | $118,453 | 17,761 | $86,596 |
| Electroplating anodes | 177 | 1,235 | 140 | 965 | 132 | 965 |
| Ferronickel | NA | NA | 7,880 | NA | 5,355 | NA |
| Powder and flakes | 1,017 | 6,973 | 1,790 | 12,062 | 1,106 | 8,942 |
| Total | 23,359 | 107,305 | [r]35,807 | 131,480 | 24,354 | 96,503 |
| Nickel content[1] | 23,359 | XX | 31,638 | XX | 21,745 | XX |
| Wrought: | | | | | | |
| Bars, rods, angles, shapes, sections | 1,582 | 18,747 | 3,342 | 34,808 | 4,253 | 45,060 |
| Plates, sheets, strip | 1,430 | 18,351 | 1,968 | 21,316 | 2,645 | 28,726 |
| Tubes, pipes, blanks, fittings, hollow bar | 348 | 7,447 | 428 | 7,929 | 303 | 6,356 |
| Wire | 1,039 | 8,831 | 1,119 | 11,166 | 954 | 9.147 |
| Nickel-compound catalysts | 3,165 | 13,940 | 2,718 | 15,156 | 3,523 | 22,811 |
| Nickel waste and scrap | 12,990 | 17,106 | 13,143 | 23,566 | 15,397 | 26,705 |
| Grand total | 43,913 | 191,727 | [r]58,525 | 245,421 | 51,429 | 235,308 |

[r]Revised. NA Not available. XX Not applicable.

[1]Based on estimated nickel content and gross weight of primary nickel products.

Source: Bureau of the Census.

### Table 7.—U.S. imports for consumption of nickel products, by class

(Gross weight unless otherwise specified)

| Class | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Primary: | | | | | | |
| Smelter products: | | | | | | |
| Ferronickel | 45,134 | $65,264 | 43,048 | $68,429 | 36,528 | $60,253 |
| Matte and/or salts (includes slurry) | 62,454 | 83,613 | 82,509 | 116,956 | 68,210 | 101,101 |
| Refined nickel: | | | | | | |
| Cathodes, pellets, briquets (unwrought) | 90,839 | 418,943 | 103,017 | 461,371 | 97,779 | 446,009 |
| Flakes | 96 | 427 | 759 | 3,306 | 242 | 1,151 |
| Oxide and oxide sinter | 4,209 | 19,083 | 5,526 | 22,413 | 5,079 | 20,722 |
| Powder | 12,629 | 65,320 | 15,070 | 75,430 | 12,511 | 66,566 |
| Total | 215,361 | 652,650 | 249,929 | 747,905 | 220,349 | 695,802 |
| Nickel content[1] | 152,333 | XX | 176,715 | XX | 157,690 | XX |
| Wrought: | | | | | | |
| Bars, plates, sheets, anodes | 1,235 | 11,531 | 2,000 | 18,036 | 3,177 | 32,276 |
| Pipes, tubes, fittings | 575 | 54,774 | 1,171 | 11,034 | 3,744 | 33,984 |
| Rods and wire | 2,241 | 17,935 | 5,419 | 28,544 | 2,990 | 22,103 |
| Shapes, sections, angles | 54 | 313 | 60 | 506 | 189 | 1,297 |
| Nickel waste and scrap | 6,071 | 17,691 | 6,199 | 20,542 | 5,552 | 16,430 |
| Grand total | 225,537 | 754,894 | 264,778 | 826,567 | 236,001 | 801,892 |

XX Not applicable.

[1]Based on estimated nickel content and gross weight of primary nickel products.

Source: Bureau of the Census.

## Table 8.—U.S. imports for consumption of nickel products, by country

(Short tons of contained nickel)

| Country | Cathodes, pellets, briquets (unwrought) | | Powder and flakes | | Oxide and oxide sinter | | Ferronickel | | Matte and salts[e] (includes slurry) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 |
| Australia | 7,680 | 8,428 | 3,545 | 2,306 | -- | -- | -- | -- | 13,487 | 7,803 |
| Botswana | 75 | -- | -- | -- | -- | -- | -- | -- | 21,324 | 11,244 |
| Canada | 55,689 | 52,130 | 10,644 | 8,433 | 4,255 | 3,770 | -- | 242 | 1,961 | 6,104 |
| Dominican Republic | -- | 7 | -- | -- | -- | -- | 8,291 | 7,754 | -- | -- |
| Finland | 4,072 | 4,771 | -- | -- | -- | -- | -- | -- | 122 | 47 |
| France | 2,035 | 2,042 | 1 | 5 | -- | -- | -- | -- | 89 | 242 |
| Germany, Federal Republic of | 536 | 56 | 166 | 223 | -- | -- | 5 | 299 | 257 | 175 |
| Japan | 29 | -- | -- | -- | -- | -- | 877 | -- | -- | 28 |
| Netherlands | 567 | 155 | -- | -- | -- | 54 | -- | -- | 9 | 12 |
| New Caledonia | -- | -- | -- | -- | -- | -- | 3,045 | 3,744 | -- | -- |
| Norway | 18,947 | 24,166 | -- | -- | -- | -- | -- | -- | -- | -- |
| Philippines | 3,923 | 635 | 818 | 664 | -- | -- | -- | -- | 26 | -- |
| South Africa, Republic of | 3,964 | 2,298 | 479 | 659 | -- | -- | 10 | 20 | 4 | 4,182 |
| Sweden | 566 | 30 | 4 | 17 | -- | -- | -- | -- | 41 | 35 |
| U.S.S.R | 60 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| United Kingdom | 878 | 417 | 170 | 231 | -- | -- | 15 | -- | 3 | 2 |
| Zimbabwe | 3,147 | 2,150 | -- | -- | -- | -- | -- | -- | -- | -- |
| Other | 849 | 494 | 2 | 215 | -- | 87 | 3,604 | 683 | 444 | 631 |
| Total | 103,017 | 97,779 | 15,829 | 12,753 | 4,255 | 3,911 | 15,847 | 12,742 | 37,767 | 30,505 |

[e] Estimated.

Source: Bureau of the Census.

# WORLD REVIEW

Excess production capacity and oversupply dominated the world nickel industry. Although early in the year consumer concerns over possible shortfalls drove the price up, the physical shortages failed to materialize. Settlement of separatist strife in New Caledonia and requalification of Nonoc nickel briquets to satisfy LME contracts eliminated these potential shortages. The U.S.S.R. resumed shipments of nickel into the LME, and ferronickel producers flooded European markets. Furthermore, Falconbridge Nikkelverk A/S, Norway, and Sherritt Gordon, Canada, announced refinery expansions. Western Platinum Ltd. (Wesplat), Republic of South Africa, began building a refinery in the Republic of South Africa. In Zimbabwe, Rio Tinto (Zimbabwe) Ltd. (RTZ) reopened its refinery to further swell effective nickel capacity. These expansions more than offset the strikes and periodic technical difficulties experienced during the year by several major producers. Instead of the anticipated shortages, world plant production actually rose slightly above the 1984 figure. By yearend, prices plummeted to their lowest point since 1983.

A major revamping of nickel traffic patterns emerged from closure of AMAX Nickel's refinery. BCL matte, previously shipped to the refinery, instead was shipped to the Falconbridge Nikkelverk refinery in Norway and the RTZ refinery in Zimbabwe. Matte from the Agnew Mine in Australia was resold by AMAX Nickel to Sherritt Gordon and Outokumpu.

Representatives of countries seeking to form an International Nickel Discussion Group (INDG) gathered in Geneva, Switzerland, during the first week in November for another in a series of formative meetings. The United States sent an observer. Representatives attended from all of the nickel producing countries, except China, and from the major consuming countries. Scope and objectives of the proposed INDG were completed; most rules were established. Two issues remained outstanding: (1) whether or not to share a secretariat with the International Lead and Zinc Study Group and (2) the formula for financing the organization. Regarding the first issue, one proposal was for an autonomous three- or four-person secretariat. The probable financing plan featured a two-part budget. One portion would be shared equally by all participating countries; the second would be prorated, based upon the member's share of the world nickel trade.

The Nickel Development Institute, founded in 1984, began operating in 1985 as a nonprofit organization dedicated to providing applications information on nickel, conducting nickel market research, and developing new markets for nickel. Headquartered in Toronto, Canada, the institute was supported by 14 major nickel producing companies. It began publishing the quarterly publication "Nickel" in September to disseminate information to industrial sectors.

**Albania.**—The year 1985 marked the end of Albania's seventh 5-year plan, which included an emphasis on boosting mine output. Nickeliferous iron ore annual production increased 91% over the annual amount produced in 1981, the first year of the plan. Discussions reportedly were held with Yugoslavia pursuant to possible exports of the ore to the Kosovo smelter.

Construction continued on a nickel-cobalt cathode refinery being built at Elbasan by the West German company Salzgitter AG using technology supplied by Inco Ltd.

**Argentina.**—At Las Aguilas near San Luis, a detailed exploration program sponsored by the Dirección General de Fabricaciones Militares identified 2.75 million tons of sulfide ore grading 1.3% to 2% nickel with considerable copper and cobalt content. Feasibility studies have not established commercial viability of production. Considering the weak nickel market and lack of mining infrastructure in the region, mine development is unlikely in the near future.

**Australia.**—A major rock fall in the Agnew Mine in Western Australia during January drastically altered the mining plan and reportedly cut production by at least 20% for several months. After AMAX Nickel decided to close its refinery in Louisiana, the matte from the Agnew Mine was sold to the Sherritt Gordon refinery in Canada and Outokumpu's refinery in Finland. Western Mining Corp. Ltd. (WMC) continued toll smelting the ore into matte at its Kambalda plant.

Nickel production in Australia received a boost with the return of the Greenvale Mine and Yabulu refinery to essentially full-scale production. Owned by Metals Exploration Ltd. and Freeport Queensland Ltd., the refinery operated at 70% of capacity in 1985.

WMC suffered several strikes. During March, lifter operators struck for 16 days in the Kambalda District. Underground miners at Kambalda struck for 11 days in July, after which mill workers went on strike for 2 days. Smelter and refinery output were not greatly affected, and production for the Australian fiscal year, which ended July 1985, remained close to that of fiscal year 1984.

Metals Exploration reopened the Nepean Mine, which had been mothballed since 1983. Ore from the mine was shipped to WMC for smelting into nickel matte. Approximately 275,000 tons of ore grading 2.7% nickel constitute enough mine reserves for 2 years of operation.

Mine production kept Australia in third place among world producers of nickel.

**Bolivia.**—The Eastern Bolivia Mineral Exploration Project, jointly conducted by the Bolivian and British geological services, revealed a significant laterite nickel deposit in eastern Bolivia. The Rincon del Tigre deposit reportedly contains 3.3 million tons of material grading 3% to 11% nickel.

**Botswana.**—AMAX Nickel released BCL from the contract to supply AMAX Nickel with matte from the Selebi and Phikwe Mines in Botswana. BCL began to fulfill the contract signed earlier in 1985 to supply matte to Falconbridge Nikkelverk's refinery in Norway and RTZ's Eiffel Flats refinery in Zimbabwe. Small amounts of matte reportedly were also shipped to Bindura Nickel Corp. Ltd.'s smelter in Zimbabwe and to Matthey Rustenburg Refiners (Pty.) Ltd.'s refinery in the Republic of South Africa.

**Canada.**—Early in the year, the Canadian Government announced that it will provide financial assistance to Canadian smelters in order to ensure that smelters are able to achieve the Government's goal of reducing by 50% sulfur dioxide ($SO_2$) emissions by 1994. Inco agreed to comply with the limits, feeling that they could be reached by retrofitting existing equipment. At yearend, however, Ontario imposed tough new $SO_2$ emission standards on nickel smelters operated by Inco and Falconbridge Ltd. in the Sudbury District. Inco must reduce its emissions from present limits of 755,000 to 292,000 tons per year by 1994. Falconbridge must lower its emissions from 170,000 to 110,000 tons per year.

Canada was second behind the U.S.S.R. in nickel mine production.

Inco, the largest nickel producer among market economy countries, posted its first annual profit since 1980. The profit occurred primarily through stringent cost-cutting efforts and modest nickel price hikes in the first half of 1985.

To reduce its work force, Inco offered several early retirement incentives. In an additional streamlining move, Inco halted electrolytic nickel refining at its Port Colborne refinery in favor of producing utility-grade nickel from its high-purity pellets.

The company thus concentrated its cathode nickel production at the Manitoba operations. Utility-grade nickel was deemed more economical to make from the pellets than from the formerly used nickel oxide because byproduct cobalt was recovered during pellet production.

Inco employees at the Sudbury and Port Colborne operations voted to accept a labor contract agreed upon by the company and the employees' union. The 3-year contract links base-pay raises and cost-of-living adjustments to the price of nickel. Falconbridge Ltd. and its labor union also agreed to a new 3-year labor contract for the Sudbury District mines. Sherritt Gordon reached accord with the union at its nickel refinery in Alberta.

Falconbridge announced a major 3-year expansion program for its Craig Mine near Sudbury. The development work is necessary to boost production after the premature closure of the Falconbridge No. 5 shaft in 1984.

Sherritt Gordon reported significantly increased nickel production and sales. As a consequence of obtaining nickel matte formerly sent to AMAX Nickel's refinery, the company expanded its Fort Saskatchewan refinery capacity from 22,000 to 25,000 tons per year.

Hudson Bay Mining and Smelting Co. Ltd. delineated a copper-nickel deposit beneath Namew Lake near Flin Flon, Manitoba. Containing approximately 1.3 million tons of ore, the deposit averages approximately 2.8% nickel with 0.7% copper. Proximity to other mining districts in Manitoba favors eventual development of the deposit despite currently depressed nickel markets.

**China.**—At the Tokyo, Japan, trade fair, the China National Nonferrous Metals Industry Corp. announced plans to double the present capacity of its Jinchuan nickel mine in the Gansu Province by 1990. Present capacity is 22,000 tons per year of cathode nickel. China signed an agreement with a Swedish consortium, including Boliden AB, to provide technology for the expansion. A conversion to undercut-and-fill mining highlights the desired technology. The expansion could convert China from a nickel importer to an exporter.

The Bechtel Group Inc., San Francisco, CA, and Galactic Resources Ltd., Canada, joined the large list of companies from market economy countries that signed cooperative agreements for mineral development in China. Galactic established a joint venture for developing a massive polymetallic sulfide deposit in the Xinjiang Uygur Autonomous Region in western China. The Bechtel letter of intent involved engineering and construction for mine development.

**Colombia.**—Shortly after rebuilding a ferronickel smelter furnace over a 2-month span, Cerro Matoso S.A. closed its smelter following another furnace failure in August. The Colombian producer did not produce ferronickel again until October. Although earlier in the year the smelter had been operating close to its effective capacity of 25,000 tons per year of nickel in ferronickel, the 5-month shutdown significantly curtailed its 1985 ferronickel production. The company was able to reschedule its debt with international banks in order to defer a portion of that debt until 1987.

**Cuba.**—Although Cuba's new Punta Gorda nickel refinery was scheduled to open late in 1984, it apparently was not inaugurated until November 1985 and did not achieve commercial production during 1985. Although Cuba expects plant capacity to eventually reach 33,000 tons per year, the immediate production goal ranges from 5,500 to 8,300 tons per year.

Meanwhile, construction proceeded on the Las Camariocas plant. An agreement between Cuba and Hungary infused more funds into the project.

**Dominican Republic.**—Falconbridge Dominicana C. por A. shipped more nickel in ferronickel than it did in each of the previous 11 years. On December 20, the ferronickel smelter began a 5-week shutdown to facilitate planned furnace maintenance and to reduce ferronickel inventories. The 1985 production was achieved with one furnace operating out of three available for duty.

**Finland.**—Outokumpu, the large state-controlled mining and metals group, continued developing the Enonkoski Mine in eastern Finland. At Laukunkangas near Savonlinna, the mine began production at yearend. The underground mine was expected to provide 440,000 tons of ore per year from sublevel stoping operations. The company's Harjavalta smelter experienced technical difficulties with its flash furnace for several weeks, necessitating production from a more expensive electric furnace.

**France.**—Société Métallurgique le Nickel (SLN) was restructured into Eramet-SLN, retroactive from January 1, 1985. Shareholders remained unchanged. The company's New Caledonia operations were placed in a separate, 100%-owned subsidiary, LeNickel-SLN. Eramet-SLN purchased all nickel produced by LeNickel-SLN except the ore sold to Japanese smelters.

The French mint decided to replace its present 10-franc coin with one of pure nickel. The plans called for producing 600 million coins with 4,300 tons of nickel over the next 5 years. Eramet-SLN was expected to supply most of the nickel.

**Greece.**—Larco S.A.'s ferronickel smelter at Larymna near Boeotia experienced a 2-week strike early in 1985. In February, shortly after the strike was settled, one of its furnaces exploded when slag leaked into a pool of water. The smelter resumed production in March at about 80% of capacity, up from the 50% to 60% utilization in 1984.

**India.**—Progress was made on plans for development of a ferronickel complex. The Industrial Promotion and Investment Corp. of Orissa procured a letter of intent from involved Government agencies to develop a 15,000-ton-per-year plant near Cuttack. The plant would be built adjacent to the corporation's Jaipur Road ferrochromium plant. Land, electric power, and transportation are readily available. Since early development of domestic deposits is unlikely, imported ore is the most likely source of material.

**Indonesia.**—P.T. International Nickel Indonesia lost an estimated production of 500 to 750 tons of nickel in matte when one furnace in its smelter overheated. The resultant damages shut the furnace down for repairs several weeks during May and June. Despite the damage to the smelter, nickel matte exports from Indonesia jumped 30% above those of 1984.

Ni-Cal Technology signed a letter of intent with P.T. Aneka Tambang (Antam), the Government-owned nickel mining operation, to establish a joint nickel-cobalt processing venture. The proposed plant would be built at Antam's Gebe Island laterite deposit. The plant's acid leaching technology would be adopted from technology developed by Ni-Cal Technology for the Gasquet Mountain deposit in the United States. Antam considered the technology as a possible method of producing pure forms of nickel to increase profitability.

**Japan.**—Ferronickel production increased significantly in 1985 compared with that in 1984, offsetting declines in pure metal production. Demand for primary nickel dropped, as evidenced, for example, by sharply lower consumption of nickel in the Ni-42 alloy used in integrated circuitry. Primary nickel stocks remained high throughout the year. The high inventories accrued in part owing to a supply contract with the Soviet export agency Raznoimport, preventing stock levels from responding to the shrinking demand. Resumption of nickel shipments from Nonoc also contributed to the heavy flow of nickel into the country.

Citing financial losses by its ferroalloys industry, Japan approved a plan submitted by its Ministry of International Trade and Industry to provide financial assistance to those producers under the Structural Reform Law. The plan called for a 12% reduction in smelting capacity by the four leading ferronickel producers in exchange for substantially reduced fixed property taxes. The law also provided tax credits for upgrading facilities. Since production in 1984 averaged about 57% of capacity, the closures will not result in a production cut.

Meanwhile, Japan encouraged increased nickel imports by accelerating by 2 years the planned tariff reduction for nickel metal, nickel oxide, and ferronickel. The tariff on ferronickel, for instance, will decrease to 6.5% from 8.3%, effective April 1, 1986.

**New Caledonia.**—Mining and smelting facilities owned by SLN in New Caledonia were restructured to comprise a new corporate subsidiary, LeNickel-SLN, effective January 1, 1985.

Political violence associated with the Kanak separatist movement adversely impacted the nickel mining operations. Raids during January shut down the major nickel mines, damaging equipment at the Camp des Sapin Mine near Thio and the Meaba Mine at Kouaoua. By March, however, SLN had reopened its Le Plateau Mine, closed since the outbreak of violence late in 1984. SLN also reported that the Meaba Mine was operating at 100% of capacity. A flareup of separatist activity in August closed the mines again for 1 week, but without additional damage to the facilities. Owing to high stockpiles of nickel ore, augmented by ore purchased from the several small independent miners on the island, SLN's Doniambo smelter near Nouméa maintained production throughout the crisis. Ferronickel production in 1985 eventually far exceeded that of 1984.

**Norway.**—Falconbridge Nikkelverk successfully negotiated a contract to receive the bulk of BCL's nickel matte production until the end of the century. The negotiations prompted the company to initiate a 3-year, $43 million expansion program at the Kristiansand refinery. Refinery capacity was expected to increase by 33% to 60,000 tons upon completion. Even before the expansion was initiated, the refinery supplied a significant portion of the primary nickel purchased by U.S. consumers. Its primary feed source remained company mines in the Sudbury District of Canada.

**Philippines.**—Production of briquet nickel resumed after Nonoc repaired damage inflicted to its refinery during the 1984 typhoon. Production rates gradually picked up during 1985. Marc Rich & Co. A.G. supplanted Philipp Bros. Inc. as sole Nonoc sales agent outside of Japan. This shift spawned several unsuccessful court challenges by Philipp Bros., hampering nickel movements. Nonoc eventually registered its briquet on the LME, facilitating sales of the product.

Ni-Cal Technology reportedly entered into an agreement with the Surigao Nickel Development and Industrial Corp. to develop and process the Catilian nickel laterite deposits. The deposits are approximately 100 miles from the nickel refinery at Surigao. Under the agreement, Surigao Nickel would mine and process the ore using Ni-Cal Technology's acid leaching process. The letter of intent parallels one signed in 1984 by Ni-Cal Technology and Nonoc.

**South Africa, Republic of.**—Wesplat neared completion of a new base metal refinery at the Marikana platinum mine near Rustenburg in Transvaal. The new refinery was to produce byproduct nickel sulfate at a rate of 2,200 tons of contained nickel per year using Sherritt Gordon technology employing a sulfuric acid leach. Meanwhile, concentrates from the platinum mine were shipped to Falconbridge Nikkelverk's refinery in Norway for extracting nickel, copper, and cobalt. The residue was then returned to Wesplat for precious metals recovery. Several scattered short labor disputes failed to significantly disrupt mine production at company mines.

**U.S.S.R.**—In late 1984, the U.S.S.R. changed its nickel sales policy to push for direct, long-term sales contracts with consumers rather than relying on sales to trading companies. The terms of the contracts fell from favor among consumers, however, as the nickel price and demand slipped. Negotiations initiated in 1985 for 1986 nickel purchases consequently marked a return to sales through traders.

Nickel mine production estimated for the U.S.S.R. increased slightly, allowing it to regain the production lead from Canada.

**Table 9.—Nickel: World mine production, by country[1]**

(Short tons of nickel content)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Albania (content of ore)[e] | 6,200 | 6,400 | 6,400 | 6,600 | 6,600 |
| Australia (content ofconcentrate) | 81,963 | 96,510 | 84,465 | 83,653 | [2]93,700 |
| Botswana (content of matte) | 18,200 | 19,573 | 20,079 | [e]19,300 | 20,000 |
| Brazil (content of ore) | [r]7,239 | [r]15,929 | 17,153 | 23,887 | 26,000 |
| Burma (content of speiss)[e] | [2]22 | 22 | 22 | 22 | 22 |
| Canada[3] | 176,642 | [r]97,644 | 141,220 | 192,017 | 167,000 |
| China[e] | 12,000 | 13,200 | 14,300 | 15,400 | 22,000 |
| Colombia (content of ferroalloys) | -- | [r]1,455 | 14,400 | 18,810 | 13,000 |
| Cuba (content of oxide, sinter, sulfide) | 42,489 | 39,790 | 41,487 | 35,087 | 35,700 |
| Dominican Republic | 20,601 | [r]5,926 | 21,552 | 26,371 | 29,000 |
| Finland (content of concentrate) | 7,566 | [r]6,980 | 5,858 | 7,638 | 7,200 |
| German Democratic Republic[e] | 3,000 | 2,800 | 2,400 | [r]2,200 | 1,800 |
| Greece (recoverable content of ore)[e] [4] | [2]17,200 | 5,500 | 18,500 | 18,400 | 19,000 |
| Indonesia (content of ore)[4] | 53,848 | 50,578 | 54,430 | 52,474 | 54,000 |
| Morocco (content of nickel ore and cobalt ore) | 144 | 140 | -- | -- | -- |
| New Caledonia (recoverable content of ore) | 86,079 | 66,250 | 50,885 | [r] [e]63,000 | 80,400 |
| Norway (content of concentrate) | [r]551 | [r]551 | 500 | 600 | 600 |
| Philippines | 32,239 | [r]21,643 | 15,322 | 14,993 | 30,300 |
| Poland (content of ore)[e] | 2,300 | 2,300 | 2,300 | 2,300 | 2,200 |
| South Africa, Republic of[e] | [2]29,100 | 24,250 | 22,600 | 27,600 | 27,600 |
| U.S.S.R. (content of ore)[e] | 174,000 | 182,000 | 187,000 | 192,000 | 198,000 |
| United States (content of ore shipped) | 12,099 | 3,203 | -- | 14,540 | [2]6,127 |
| Yugoslavia (content of ore)[e] | [r]2,200 | 4,400 | 3,300 | 4,400 | 5,500 |
| Zimbabwe (content of concentrate) | 14,350 | 14,671 | 11,186 | 11,300 | 11,000 |
| **Total** | **[r]800,032** | **[r]681,715** | **735,359** | **832,592** | **856,749** |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Insofar as possible, this table represents recoverable mine production of nickel; where data relate to some more highly processed form, the figure given has been used in lieu of unreported actual mine output to provide some indication of the magnitude of mine output and is so noted parenthetically following the country name, or by footnote. Table includes data available through May 13, 1986.

[2] Reported figure.

[3] Refined nickel and nickel content of oxides and salts produced, plus recoverable nickel in exported mattes and speiss.

[4] Includes a small amount of cobalt not reported or recovered separately.

Table 10.—Nickel: World plant production, by country[1]

(Short tons of nickel content)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Australia[3] | 46,854 | 50,630 | 46,077 | 42,615 | [4]44,982 |
| Brazil[5] | 2,574 | [r]3,826 | 9,165 | 10,127 | 13,200 |
| Canada[6] | 120,486 | 64,635 | [e]96,100 | [e]114,600 | 100,300 |
| China[e] | 12,100 | 13,200 | 14,300 | 15,400 | 22,000 |
| Colombia[5] | -- | [r]1,455 | 14,396 | 18,810 | 13,000 |
| Cuba[7] | 9,355 | [r]9,922 | 10,298 | 9,311 | 9,370 |
| Czechoslovakia[e] | [r]1,800 | [r]1,700 | [r]3,300 | [r]5,000 | 5,000 |
| Dominican Republic[5] | 20,601 | 5,812 | 23,369 | 26,698 | [4]28,450 |
| Finland | 14,672 | 13,906 | 16,355 | 16,846 | 17,300 |
| France[6] | 11,079 | 8,114 | 8,047 | 5,751 | 5,500 |
| German Democratic Republic[e] | 3,100 | 3,300 | 3,300 | 3,300 | 3,300 |
| Germany, Federal Republic of[e] [8] | 1,320 | 1,320 | 1,320 | 1,100 | 1,100 |
| Greece | 14,000 | [e]5,000 | 14,174 | 17,448 | 17,600 |
| Indonesia[5] | 5,184 | 5,523 | 5,352 | 5,320 | 5,500 |
| Japan | 95,679 | 91,886 | 76,667 | 81,789 | [4]85,419 |
| New Caledonia[5] | 30,853 | 30,871 | 23,939 | 32,141 | [4]40,108 |
| Norway | [r]40,735 | [r]28,476 | 31,205 | 39,185 | [4]41,351 |
| Philippines | 23,683 | [r]12,371 | 6,721 | 3,889 | [4]18,360 |
| Poland[e] | [r]2,300 | [r]2,300 | [r]2,300 | [r]2,300 | 2,300 |
| South Africa, Republic of | 19,800 | 15,900 | [e]18,740 | 22,597 | 22,000 |
| U.S.S.R.[e] | 196,200 | 198,400 | 204,000 | 214,000 | 220,000 |
| United Kingdom | 27,999 | 7,606 | 25,574 | 24,582 | 15,400 |
| United States | 48,805 | 44,956 | 33,400 | 44,933 | [4]36,382 |
| Yugoslavia[e] | -- | 1,700 | 1,700 | 2,200 | 3,300 |
| Zimbabwe | [e]13,200 | [e]13,200 | 11,184 | 11,300 | 11,000 |
| Total | [r]762,379 | [r]636,009 | 700,983 | 771,242 | 782,222 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Refined nickel plus nickel content of ferronickel produced from ore and/or concentrates unless otherwise specified. Table includes data available through May 13, 1986.

[2] In addition to the countries listed, North Korea is believed to have produced metallic nickel and/or ferronickel, but information is inadequate for formulation of reliable estimates of output levels. Several countries produced nickel-containing matte, but output of nickel in such materials have been excluded from this table to avoid double counting. Countries producing matte include the following, with output indicated in short tons of contained nickel: Australia: 1981—36,223; 1982—54,444; 1983—54,900 (revised, estimated); 1984—56,330; and 1985—56,858; Botswana: 1981—20,143; 1982—19,573; 1983—20,080; 1984—20,507 (revised); and 1985—20,500 (estimated); Indonesia: 1981—21,980; 1982—15,156 (revised); 1983—20,159 (revised); 1984—25,149 (revised); and 1985—27,900 (estimated); and New Caledonia: 1981—16,954; 1982—7,875; 1983—5,046 (revised); 1984—6,219 (revised); and 1985—9,233.

[3] Refined nickel plus the nickel content of oxide.

[4] Reported figure.

[5] Nickel content of ferronickel only. (No refined nickel was produced.)

[6] Includes nickel content of refined nickel, nickel oxide, and nickel matte; from 1982, the totals for France are production of nickel cathodes only.

[7] Content of granular nickel oxide and powder only; Cuba also produces nickel oxide sinter and a processed sulfide, but these are not included in order to avoid double counting, as they may be processed to metal elsewhere. Output of sinter was as follows, in short tons: 1981—13,354; 1982—12,952 (revised); 1983—12,723 (revised); 1984—9,804 (revised); and 1985—9,900 (estimated). Output of processed sulfide was as follows, in short tons: 1981—19,779; 1982—16,916 (revised); 1983—18,466 (revised); 1984—15,971 (revised); and 1985—16,400 (estimated).

[8] Includes nickel content of nickel alloys.

**United Kingdom.**—Inco Europe Ltd., a subsidiary of Inco Ltd., shut down the Clydach refinery for 3 months early in 1985. The shutdown stemmed from the company's desire to reduce stocks to a level consistent with market conditions. Approximately 370 of the refinery's 537 workers were layed off during the shutdown, and the permanent staff was reduced by 69 by yearend. Nickel chloride and sulfate production continued during closure of the nickel pellet and powder facility. The plant resumed production in April at about 50% of its capacity.

**Yugoslavia.**—Rudnik i Topionica Feronikl brought a second furnace line onstream at its Kosovo ferronickel smelter. The startup raised production to about 30% of the plant's expected capacity. Ferronickel was exported to Austria, the Federal Republic of Germany, and Italy. Discussions reportedly were held with Albanian officials regarding processing of Albanian nickeliferous iron ore at the Kosovo smelter.

The Government solicited buyers for the plant equipment from the Kavadarci smelter. The plant closed in June 1984 after only 2 years of operation.

**Zimbabwe.**—The Eiffel Flats refinery reopened in August to process matte purchased from BCL. The refinery, operated by Empress Nickel Mining Co. Ltd., a subsidiary of RTZ, produced cathode nickel by yearend at close to its target rate of 400 tons per month.

## TECHNOLOGY

**Mining and Processing.**—Inco Ltd. continued to focus its attention on new technical developments that could improve productivity and safety in its underground mines. For improved ground support, a spray-on, fiberglass-reinforced epoxy resin was developed to reduce time-consuming rock bolt installation. Modifications were made to the continuous loading machine marketed by its subsidiary, Continuous Mining Systems Ltd. (CMS), to enable the loader to discharge onto a conveyor that follows the machine as it moves through the muck. CMS also participated in the development of a conveyor belt that goes around corners.

France continued to pioneer the development of equipment for recovering seafloor nodules. A consortium of French ocean mining companies, in conjunction with the French National Center for Ocean Exploitation, developed two totally autonomous, remotely operated submarine vehicles. The vehicles can be accurately guided to specific spots of the ocean floor at depths to 6,000 meters. One vehicle, the Epaulard, equipped with lights and cameras for reconnaissance, has completed 100 dives. The other, PLA 2, was designed to move along the ocean floor on tracks, scooping up nodules before returning to the mother ship. The battery-operated vehicle is controlled by a microprocessor.

Numerous research programs were devoted to the recovery of nickel from spent petroleum catalysts. AMAX Nickel successfully completed a pilot program on its process at its shuttered Port Nickel refinery. The experiments were conducted under a joint program with Catalyst Recovery Inc. and Shell Chemical Inc. The AMAX Nickel process yielded a nickel-cobalt sulfate that can be sold as is or reprocessed into pure metal.

**Nickel Products.**—Allied Corp. announced the development of a new nickel alloy, Altraloy, that may replace gold in some electronic circuit applications. Although gold traditionally is used because it resists corrosion and has a low contact resistance, the new alloy reportedly has similar properties at a lower cost.[4]

Wall Colomony, United Kingdom, offered a new nickel-based hard-surfacing alloy as an alternative to cobalt-based ones. This new alloy is claimed to be easy to deposit and self-fluxing, in addition to being wear resistant.

Developments in amorphous powder metals continued to mount. Allied, one of the leaders in such developments, produced a nickel-molybdenum-boron alloy with superior hardness and toughness properties using an extrusion process.

**End Uses.**—Cummins Engine Co. received the first commercial license to produce a new nickel-aluminide alloy for use in diesel engines and turbochargers. The alloy, containing 85% nickel, is 10% lighter than present superalloys. It contains no chromium or cobalt, which should reduce reliance on these strategic materials. More importantly, the alloy offers advantageous performance characteristics at high temperatures over those of current superalloys and was expected to replace the current ones in many applications.

The United States Steel Corp. became the second major U.S. company to recently introduce a nickel-coated terne sheet into its product line. Formed by electroplating nickel onto cold-rolled steel sheets before they are dipped into the lead-tin alloy terne bath, the sheets are much more corrosion-resistant than nonnickel terne sheets. With numerous applications in the automobile and heat and air-conditioning industries, the new product offered excellent opportunities for significantly increasing nickel sales in the United States.

Potential applications proliferated for nitinol, a nickel-titanium alloy developed by the Naval Ordnance Laboratory in White Oak, MD. The material features the unique ability to retain a "memory" of its original shape and to return to that shape upon reheating. Nitinol engines have attracted much attention because of their potential to run only on minimal heat energy. The material also looks promising for a variety of surgical applications including bone setting, correction of scoliosis, and reinforcement of artery walls. Switches for fire alarm systems, automatically opening windows, and supports for brassieres are other successful applications of nitinol.[5]

Renovation proceeding on the Statue of Liberty features a high-nickel-content stainless steel support structure for the copper external skin. The 23 tons of material (mostly type 316 L), donated by several domestic producers, replaces the original iron support structure that was prone to corrosion.[6]

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[1] Physical scientist, Division of Ferrous Metals.

[2] U.S. Department of the Interior, Bureau of Mines staff, and U.S. Department of Commerce, Basic Industries Sector staff. Domestic Consumption Trends, 1972-82, and Forecasts to 1993 for Twelve Major Metals. BuMines OFR 27-86, Jan. 1986, 158 pp.

[3] Metals Week. Metals Week Annual Prices. V. 57, No. 2, Jan. 13, 1986, p. 10.

[4] American Metal Market. New Nickel Alloy Could Replace Electronics Gold. V. 93, No. 185, p. 5.

[5] Morris, S. Games. Omni, v. 8, No. 8, May 1986, pp. 148-149.

[6] Bowers, E. W. The Lady Is Being Saved. Phoenix Q., v. 17, Summer 1985, pp. 2-6.

# Nitrogen

## By Charles L. Davis[1]

U.S. production of anhydrous ammonia, 82.2% nitrogen, was about the same as that of 1984. The total value of ammonia produced and sold decreased to about $1.8 billion. The value of apparent consumption decreased to about $2 billion. Production and apparent consumption values were based on average annual 1985 f.o.b. gulf coast spot prices, which decreased considerably during the year. Imports of ammonia also decreased. An increase in ammonia exports was attributed to aggressive marketing practices by U.S. ammonia exporters and the appearance of a temporary European market.

**Domestic Data Coverage.**—Domestic production data for ammonia were developed by the Bureau of the Census, U.S. Department of Commerce, and published monthly in Current Industrial Reports, Inorganic Fertilizer Materials and Related Products, M28B. The Department of Commerce surveyed approximately 62 firms manufacturing inorganic fertilizer chemicals. Production estimates were supplied for reports not received in time for tabulation. These data are shown in table 1.

**Table 1.—Salient ammonia statistics**

(Thousand short tons of contained nitrogen)

| | 1981 | 1982 | 1983 | 1984 | 1985[p] |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production[1] [2] | 15,782 | 13,029 | 11,297 | 13,368 | 13,238 |
| Exports | 506 | 610 | 298 | 438 | 1,010 |
| Imports for consumption | 1,719 | 1,787 | 2,169 | 2,699 | 2,306 |
| Consumption[2] [3] | 16,467 | 14,145 | 13,719 | 15,846 | 14,439 |
| World: Production | [r]84,847 | [r]83,630 | 86,560 | [p]93,029 | [e]94,302 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Synthetic anhydrous ammonia and coke oven ammonia.

[2]Coke oven ammonia not available for 1985.

[3]Includes producers' stock changes in synthetic anhydrous ammonia and coke oven ammonia.

## DOMESTIC PRODUCTION

Monthly production in 1985 remained above that of 1984 through July, then declined each month for the remainder of the year. The greatest production occurred in March, nearly 1.5 million short tons, and the lowest in December, almost 1.2 million tons. Several ammonia plants were closed because of poor markets; two closed because of explosions at the plant. By yearend, a total of about 2 million tons of plant capacity was closed for an indefinite period. Ammonia was produced by 43 companies at 55 plants in 23 States.

## Table 2.—Fixed nitrogen production in the United States

(Thousand short tons of contained nitrogen)

| | 1981 | 1982 | 1983 | 1984 | 1985[p] |
|---|---|---|---|---|---|
| Ammonium compounds, coking plants: | | | | | |
| Ammonia liquor[1] | 2 | 5 | 5 | 5 | NA |
| Ammonium phosphate[1] | (2) | (2) | (2) | (2) | NA |
| Ammonium sulfate[1] | 75 | 56 | 46 | 54 | NA |
| Anhydrous ammonia, synthetic plants[3] | 15,655 | 12,968 | 11,246 | 13,309 | 13,238 |
| Total | 15,732 | 13,029 | 11,297 | 13,368 | 13,238 |

[p] Preliminary. NA Not available.
[1] Quarterly Coal Report, U.S. Department of Energy, Jan.-Mar. 1985, published July 1985.
[2] Included with ammonium sulfate to avoid disclosing company proprietary data.
[3] Current Industrial Reports, Bureau of the Census.

## Table 3.—Major nitrogen compounds produced in the United States

(Thousand short tons, gross weight)

| Compound | 1983 | 1984 | 1985[p] |
|---|---|---|---|
| Acrylonitrile | 1,073 | 1,101 | 1,178 |
| Ammonium nitrate | 6,628 | 7,009 | 6,907 |
| Ammonium phosphate | 12,814 | 14,468 | 12,878 |
| Ammonium sulfate[1] | 1,964 | 2,107 | 2,049 |
| Nitric acid | 7,367 | 8,016 | 7,808 |
| Urea | 5,771 | 7,188 | 6,478 |

[p] Preliminary.
[1] Excludes ammonium sulfate from coking plants.

Sources: Bureau of the Census and International Trade Commission.

## Table 4.—Domestic producers of anhydrous ammonia in 1985

(Thousand short tons per year of ammonia)

| Company | Location | Capacity |
|---|---|---|
| Agrico Chemical Co | Donaldsonville, LA | 468 |
| Do | Verdigris, OK | 840 |
| Air Products and Chemicals Inc | New Orleans, LA | 210 |
| Do | Pace Junction, FL | 100 |
| Allied Chemical Corp | Hopewell, VA | 340 |
| American Cyanamid Co | Fortier, LA | 580 |
| Arcadian Corp | Geismar, LA | 340 |
| Do | La Platte, NE | 172 |
| Atlas Chemical Industries Inc | Joplin, MO | 136 |
| Borden Chemical Co | Geismar, LA | 400 |
| Carbonaire Co. Inc | Palmerton, PA | 35 |
| Cargill Inc | Columbus, MS | 68 |
| C.F. Industries Inc | Donaldsonville, LA | 1,740 |
| Chevron Chemical Co | Pascagoula, MS | 590 |
| Do | El Segundo, CA | 20 |
| Do | Fort Madison, IA | 95 |
| Columbia Nitrogen Corp | Augusta, GA | 510 |
| Cominco American Incorporated | Borger, TX | 400 |
| Diamond Shamrock Chemical Corp | Dumas, TX | 160 |
| The Dow Chemical Co | Freeport, TX | 115 |
| E. I. duPont de Nemours & Co. Inc | Beaumont, TX | 440 |
| Farmland Industries Inc | Fort Dodge, IA | 210 |
| Do | Dodge City, KS | 210 |
| Do | Enid, OK | 840 |
| Do | Lawrence, KS | 340 |
| Do | Pollock, LA | 420 |
| First Mississippi Corp | Donaldsonville, LA | 400 |
| Georgia-Pacific Corp | Plaquemine, LA | 196 |
| Goodpasture Inc | Dimmitt, TX | 40 |
| W. R. Grace & Co | Woodstock, TN | 340 |
| Grace-Oklahoma Nitrogen | Woodward, OK | 450 |
| Green Valley Chemical Corp | Creston, IA | 35 |
| Hooker Chemical Co | Tacoma, WA | 28 |
| International Minerals & Chemical Corp | Sterlington, LA | 770 |
| Jupiter Chemical Co | Lake Charles, LA | 78 |
| Mississippi Chemical Corp | Yazoo City, MS | 393 |

Table 4.—Domestic producers of anhydrous ammonia in 1985 —Continued

(Thousand short tons per year of ammonia)

| Company | Location | Capacity |
|---|---|---|
| Monsanto Co | Luling, LA | 650 |
| N-Ren Corp | Pryor, OK | 94 |
| Do | East Dubuque, IL | 228 |
| Do | Carlsbad, NM | 68 |
| Olin Corp | Lake Charles, LA | 490 |
| Pennwalt Chemical Co | Portland, OR | 8 |
| Phillips Pacific Chemical Co | Kennewick, WA | 155 |
| Phillips Petroleum Co | Beatrice, NE | 228 |
| PPG Industries Inc | Natrium, WV | 50 |
| Reichhold Chemicals Inc | St. Helens, OR | 90 |
| J. R. Simplot Co | Pocatello, ID | 108 |
| Sohio Chemical Co | Lima, OH | 475 |
| Tennessee Valley Authority | Muscle Shoals, AL | 74 |
| Terra Chemical International | Port Neal, IA | 210 |
| Triad Chemical Co | Donaldsonville, LA | 340 |
| Union Chemical Co | Kenai, AK | 1,190 |
| Do | Brea, CA | 228 |
| U.S.S. Agri-Chemicals Inc | Cherokee, AL | 175 |
| Wycon Chemical Co | Cheyenne, WY | 108 |
| Total | | 17,398 |

Source: Economics and Marketing Research Section, Tennessee Valley Authority. World Fertilizer Capacity, Ammonia. Muscle Shoals, AL, Jan. 7, 1986.

## CONSUMPTION AND USES

The small decrease in domestic ammonia consumption in part reflected a decline in the demand for ammonia-based chemicals in the farm market. Imports of anhydrous ammonia decreased 15%, while ammonia exports increased 131%. Approximately 80% of the ammonia consumed was used in fertilizers. Ammonia also was used to produce plastics, fibers, and resins, 10%; explosives, 4%; and numerous other chemicals, 6%.

## STOCKS

Producers' stocks of ammonia on hand at the beginning of the year totaled about 1.7 million tons of contained nitrogen. At yearend, stocks totaled about 1.8 million tons of contained nitrogen. At yearend 1984, stocks had tended to increase to meet seasonal demand for spring planting; however, in 1985, stock levels remained static because of uncertain domestic demand and falling prices.

## PRICES

Ammonia prices started the year at an annual high of nearly $150 per ton. The price held steady until the middle of May, then began a steady decline until the annual low of about $107 was reached at yearend. The use of other less costly nitrogen fertilizers, lighter applications of ammonia, and ammonia imports contributed to the drop in ammonia prices.

### Table 5.—Price quotations for major nitrogen compounds at yearend 1985

(Per short ton)

| Compound | Price |
|---|---|
| Ammonium nitrate: Delivered Corn Belt | $112-$133 |
| Ammonium sulfate: F.o.b. Corn Belt | 88- 119 |
| Anhydrous ammonia: | |
| Delivered Corn Belt | 160- 170 |
| F.o.b. gulf coast | 107- 110 |
| Diammonium phosphate: F.o.b. central Florida | 139- 147 |
| Urea: | |
| Delivered Corn Belt | 110- 137 |
| F.o.b. gulf coast, granulated | 98- 101 |
| F.o.b. gulf coast, prilled | 82- 95 |

Source: Green Markets, Fertilizer Market Intelligence Weekly, Dec. 23, 1985.

## FOREIGN TRADE

Anhydrous ammonia exports increased 131% from the 438,000 tons of contained nitrogen exported in 1984. The increase was attributed to aggressive marketing in some Western European countries, Taiwan, Tunisia, Turkey, and in countries where plants had experienced production problems. The gross weight of downstream nitrogen compounds exported for industrial and fertilizer uses was about the same as that of 1984. Diammonium phosphate, urea, and anhydrous ammonia led in export tonnage of nitrogen compounds.

Imports of anhydrous ammonia for fertilizer use decreased 15%. Canada was the leading foreign supplier of ammonia to the United States with about 1.1 million tons. The U.S.S.R. supplied about 794,029 tons; Trinidad and Tobago, 531,599 tons; and Mexico, 147,641 tons. Ammonia imports from Canada and Italy increased, whereas imports from Mexico, Trinidad and Tobago, and the U.S.S.R. decreased.

### Table 6.—U.S. exports and imports for consumption of major nitrogen compounds in 1985

(Thousand short tons and thousand dollars)

| Compound | Gross weight | Nitrogen content | Value |
|---|---|---|---|
| EXPORTS | | | |
| Fertilizer materials: | | | |
| Ammonium nitrate | 127 | 43 | 13,058 |
| Ammonium sulfate | 725 | 152 | 48,468 |
| Anhydrous ammonia | 1,229 | 1,010 | 172,231 |
| Diammonium phosphate | 6,758 | 1,216 | 1,048,322 |
| Nitrogen solutions | 86 | 12 | 3,055 |
| Sodium nitrate | 24 | 4 | 3,914 |
| Urea | 1,154 | 531 | 148,857 |
| Mixed chemical fertilizers | 109 | 11 | 20,435 |
| Other ammonium phosphates | 575 | 63 | 88,176 |
| Other nitrogen fertilizers | 56 | 11 | 4,840 |
| Industrial chemicals: | | | |
| Ammonia, aqua (ammonia content) | 2 | 2 | 200 |
| Ammonium nitrate | 1 | (1) | 83 |
| Ammonium phosphate | 1 | (1) | 2,106 |
| Ammonium sulfate | 2 | (1) | 143 |
| Total | 10,799 | 3,055 | 1,553,387 |
| IMPORTS | | | |
| Fertilizer materials: | | | |
| Ammonium nitrate | 561 | 188 | 56,855 |
| Ammonium nitrate-limestone mixtures | 2 | (1) | 201 |
| Ammonium sulfate | 403 | 85 | 33,918 |
| Anhydrous ammonia | 2,806 | 2,306 | 380,173 |
| Calcium cyanamide or lime nitrogen | 2 | (1) | 616 |

See footnotes at end of table.

**Table 6.—U.S. exports and imports for consumption of major nitrogen compounds in 1985 —Continued**

(Thousand short tons and thousand dollars)

| Compound | Gross weight | Nitrogen content | Value |
|---|---|---|---|
| IMPORTS —Continued | | | |
| Fertilizer materials —Continued | | | |
| Calcium nitrate | 189 | 21 | 11,456 |
| Diammonium phosphate | 50 | 9 | 8,235 |
| Nitrogen solutions | 188 | 60 | 20,877 |
| Potassium nitrate | 46 | 6 | 10,568 |
| Potassium nitrate-sodium nitrate mixtures | 81 | 5 | 4,041 |
| Sodium nitrate | 142 | 23 | 14,672 |
| Urea | 2,165 | 996 | 262,480 |
| Mixed chemical fertilizers | 189 | 14 | 25,028 |
| Other ammonium phosphates | 127 | 14 | 21,077 |
| Other nitrogen fertilizers | 100 | 20 | 18,014 |
| Industrial chemicals: | | | |
| Ammonium nitrate | 98 | 34 | 12,698 |
| Ammonium phosphate | 950 | 177 | 515 |
| Ammonium sulfate | 598 | 126 | 120 |
| Anhydrous ammonia and chemical-grade aqua | 2 | 2 | 809 |
| Total | 8,544 | 4,086 | 880,348 |

[1] Less than 1/2 unit.

Source: Bureau of the Census.

## WORLD REVIEW

A proliferation of new ammonia plant project proposals began in 1985. In addition to the countries discussed in this section, Argentina, Australia, Chile, Finland, Indonesia, Saudi Arabia, Sweden, Trinidad and Tobago, and Turkey either were proposing or were engaged in constructing ammonia projects because of an anticipated increase in world demand by the late 1980's. In 1985, developing countries were becoming self-sufficient in supplying their agricultural fertilizer demands as a result of technology transfer from developed industrial countries. Countries with abundant state-owned, relatively inexpensive natural gas feedstock constructed world capacity ammonia plants whose product, destined for export, captured established markets. Producers from some market economy countries entered into agreements with countries having an ample supply of state-owned natural gas and constructed export-oriented ammonia and urea plants in those countries. State-owned companies operated over 60% of the world ammonia capacity. The economics affecting the overall cost of ammonia worldwide were capital cost of new plants and equipment and costs of management, energy, and transportation. Eastern European countries dominated the world ammonia trade, although the quantity of ammonia for export from Central America was increasing.

**Canada.**—Ocelot Industries Ltd. of Calgary began construction on its $80 million ammonia complex at Kitimat on the coast of British Columbia. The 200,000-ton-per-year complex was a joint venture with Devco International of Tulsa, OK. Production was scheduled to start in July 1986.[2] Cominco Ltd. and Alberta Energy Co. Ltd. announced the formation of a joint venture to construct a 385,000-ton-per-year ammonia plant in Alberta.[3]

**China.**—Construction began on an ammonia-urea complex in Yinchuan to produce 550,000 tons per year of urea.[4]

**Greece.**—A new 130,000-ton-per-year ammonia unit under construction at Kavalla for Phosphoric Fertilizer Industry Ltd. was completed.[5]

**India.**—Construction on three ammonia-urea plants was progressing approximately on schedule. The plants were to use gas from the new Hazira-Bijaipur-Jagdishpur pipeline. Each project was designed with a 1,350-ton-per-day unit.[6] Construction of a new ammonia-urea plant was begun at Bajwa in the western State of Gujarat. The plant was to have a capacity of 165,000 tons per year of ammonia and 113,000 tons per year of urea.[7]

**Iran.**—Commissioning began in June of the Shiraz fertilizer complex, which consisted of a 198,000-ton-per-year nitric acid plant, a 220,000-ton-per-year ammonium nitrate plant, a 495,000-ton-per-year urea plant, and a 396,000-ton-per-year ammonia plant. The complex was expected to supply more than $200 million worth of fertilizer per year.[8]

**Kuwait.**—Petrochemical Industries Corp. commissioned a new 300,000-ton-per-year ammonia plant at Shuaiba.[9]

**Poland.**—A second 248,000-ton-per-year ammonia plant at the fertilizer complex in Police was constructed and due to start up in 1986.[10]

**Somalia.**—The ammonia-urea complex at the port of Mogadisho was scheduled for full production early in 1985. The design capacity of the plant was 150 tons per day, and 85% of the output was designated for the export market.[11]

**U.S.S.R.**—Construction of the 600,000-ton-per-year nitrophosphate complex at Rossoh was ahead of schedule; it was due for completion late in the year. A similar complex had gone on-stream in 1984. The nitrogen fertilizer complex at Mary in Turkmenia was completed in 1985, but commissioning was delayed.[12]

### Table 7.—Ammonia: World production, by country[1]

(Thousand short tons of contained nitrogen)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Afghanistan[e] | 10 | 9 | 9 | [r]9 | 10 |
| Albania[e] | 84 | 84 | 84 | 88 | 88 |
| Algeria | [r]48 | [r]181 | 145 | 161 | 165 |
| Argentina | 44 | 64 | 63 | 56 | 55 |
| Australia | 352 | 270 | 424 | 414 | 413 |
| Austria[e] | 536 | 535 | 546 | [r]550 | 550 |
| Bangladesh | 168 | 201 | 197 | 389 | 400 |
| Belgium | 649 | 561 | 495 | 498 | 375 |
| Brazil | 414 | 555 | 814 | [e]830 | 830 |
| Bulgaria | [r]1,128 | [r]1,138 | 1,238 | 1,254 | 1,543 |
| Burma[e] | 65 | 56 | 59 | [r]63 | [3]139 |
| Canada | 2,399 | 2,278 | 3,183 | 3,351 | 3,900 |
| China[e] | 13,440 | 14,010 | 15,200 | 15,400 | 16,500 |
| Colombia | 101 | 108 | 112 | 103 | 105 |
| Cuba | 184 | 108 | 95 | 189 | 220 |
| Czechoslovakia[e] | 937 | 937 | 937 | 937 | 882 |
| Denmark | 84 | 34 | 13 | 17 | 17 |
| Egypt | 571 | 704 | 998 | 756 | 756 |
| Finland | 76 | 71 | 75 | 76 | 77 |
| France[e] | 2,500 | 2,200 | 2,100 | 2,200 | 2,300 |
| German Democratic Republic | 1,328 | 1,290 | 1,335 | 1,325 | 1,334 |
| Germany, Federal Republic of | 2,163 | 1,781 | 1,877 | 2,164 | 1,747 |
| Greece | [r]258 | [r]246 | [e]248 | [r] [e]248 | 248 |
| Hungary | 902 | [r]873 | [e]896 | 897 | 898 |
| Iceland[e] | 8 | [r]8 | [r]8 | [r]8 | 8 |
| India[4] | [r]3,506 | 3,824 | 3,930 | 4,382 | 4,520 |
| Indonesia | 1,014 | 1,183 | 1,268 | 1,328 | 1,360 |
| Iran[e] | 220 | [r]29 | [r]32 | [r]24 | 359 |
| Iraq[e] | [4]88 | 88 | 88 | [r]88 | 66 |
| Ireland | 321 | [r]409 | 324 | 409 | 386 |
| Israel | [r]47 | [r]54 | 59 | 63 | 63 |
| Italy | 1,331 | 1,153 | 1,169 | [e]1,200 | 1,300 |
| Japan | 2,020 | 1,821 | 1,708 | 1,839 | 1,820 |
| Korea, North[e] | 500 | 500 | 500 | 500 | 500 |
| Korea, Republic of | 823 | 599 | 474 | 512 | 487 |
| Kuwait | 235 | 202 | 452 | 426 | 459 |
| Libya[e] | 165 | 210 | 230 | 230 | 248 |
| Malaysia | 41 | 31 | 32 | 43 | 40 |
| Mexico | 1,979 | 2,237 | 2,184 | 1,954 | 2,000 |
| Netherlands | 2,000 | 1,824 | 1,926 | 2,547 | 2,500 |
| New Zealand | -- | -- | 48 | 64 | 66 |
| Norway | 601 | 574 | 619 | 696 | [3]576 |
| Pakistan[5] | [r]778 | [r]1,033 | 1,211 | 1,243 | 1,270 |
| Peru[e] | 107 | 93 | 94 | 94 | 94 |
| Philippines | 36 | 16 | 22 | 18 | 17 |
| Poland | 1,531 | [r]1,521 | 1,571 | 1,647 | 1,382 |
| Portugal[e] | [3]147 | 146 | 149 | 154 | 165 |
| Qatar | 404 | 478 | 646 | 696 | 724 |
| Romania | 2,625 | 2,852 | 3,006 | 2,976 | 2,976 |
| Saudi Arabia | 187 | 229 | 211 | 230 | 229 |
| South Africa, Republic of | 608 | 629 | 634 | 639 | 639 |
| Spain | 819 | 593 | 678 | [e]683 | 672 |
| Sri Lanka | 48 | 114 | 69 | [e]77 | 33 |
| Sweden | 87 | 85 | 53 | 54 | 55 |
| Switzerland | 36 | 36 | 36 | 33 | 33 |
| Syria | 33 | 72 | 125 | 132 | 132 |
| Taiwan | 448 | 350 | 342 | 296 | 230 |

See footnotes at end of table.

### Table 7.—Ammonia: World production, by country[1] —Continued

(Thousand short tons of contained nitrogen)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Trinidad and Tobago | [r]438 | [3]778 | 1,095 | 1,190 | 1,200 |
| Turkey | [r]313 | [r]281 | 307 | 320 | 320 |
| U.S.S.R. | 14,220 | 15,400 | 16,000 | 16,000 | 17,100 |
| United Arab Emirates | -- | -- | -- | 309 | 402 |
| United Kingdom | 1,962 | 1,892 | 1,896 | 2,024 | 2,000 |
| United States[6] | 15,732 | 13,029 | 11,297 | 13,368 | [3]13,238 |
| Venezuela | 457 | [r]485 | 418 | [e]510 | 513 |
| Yugoslavia | 464 | 465 | 452 | [e]440 | 460 |
| Zambia | 20 | 30 | 31 | 31 | 31 |
| Zimbabwe[e] | 57 | 93 | 78 | 83 | 77 |
| Total | [r]84,847 | [r]83,630 | 86,560 | 93,029 | 94,302 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Table includes data available through May 13, 1986.

[2]In addition to the countries listed, Vietnam has a nitrogen (N content of ammonia) production capacity of about 60,000 short tons per year; it is not known at what output level the plant is operating.

[3]Reported figure.

[4]Data are for years beginning Apr. 1 of that stated.

[5]Series revised to provide calendar year data, as opposed to fiscal year data provided in previous editions.

[6]Synthetic anhydrous ammonia and coke oven ammonia. Coke oven ammonia not available for 1985.

## TECHNOLOGY

British Petroleum Co. Ltd. developed new ammonia process technology around a graphite-based synthesis catalyst. The catalyst was to be tested in a commercial plant after initial tests at a pilot plant. The new process offered potential savings in energy and production costs.[13]

The Dow Chemical Co. developed a modular air separation system based on a newly designed membrane fiber. The fiber's thickness allows the system to have greater surface area for higher nitrogen absorption. The system was designed to yield 95% to 99% pure nitrogen.[14]

S. R. Martin, a chemical engineering consultant from Welwyn Garden City in the United Kingdom, developed a new method of steam reforming light hydrocarbons to produce synthesis gas for ammonia. The technology was centered around a thermic steam reformer. The method was more energy efficient than conventional reformers because of a low pressure drop across the heat transfer surface.[15]

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[1]Physical scientist, Division of Industrial Minerals.

[2]European Chemical News. V. 44, No. 1181, 1985, p. 25.

[3]Green Markets. V. 9, No. 24, 1985, p. 1.

[4]Nitrogen (London). No. 155, 1985, p. 16.

[5]Page 18 of work cited in footnote 4.

[6]Work cited in footnote 4.

[7]Green Markets. V. 9, No. 14, 1985, p. 5.

[8]Nitrogen (London). No. 156, 1985, p. 17.

[9]———. No. 158, 1985, p. 18.

[10]Page 16 of work cited in footnote 8.

[11]Page 12 of work cited in footnote 9.

[12]Page 11 of work cited in footnote 9.

[13]European Chemical News. V. 45, No. 1194, 1985, p. 19.

[14]Chemical Marketing Reporter. V. 227, No. 8, 1985, pp. 7-19.

[15]Page 32 of work cited in footnote 9.

# Peat

## By Charles L. Davis[1]

Peat production in the United States increased slightly in 1985. In decreasing order of quantity, Florida, Michigan, Illinois, Colorado, and Indiana were the major peat producing States. Reed-sedge peat was the most common kind produced, followed by humus, hypnum, sphagnum, and unclassified. Peat sold in packaged form by domestic producers increased in quantity and value. Apparent consumption increased slightly. Imports for consumption, primarily from Canada, decreased somewhat and represented a large part of apparent consumption. The predominant end use of peat was for agricultural and horticultural purposes. About 11,000 short tons of peat was used for fuel, mostly in projects to evaluate the burn characteristics of peat for energy production.

**Domestic Data Coverage.**—Domestic production data for peat are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the 117 operations to which a survey request was sent, 98 responded, representing 95% of the total production shown in table 1. Production for the 19 nonrespondents was estimated using prior year production levels adjusted for regional production trends and inflation.

**Table 1.—Salient peat statistics**

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Number of active operations | 90 | 93 | 94 | 101 | 99 |
| Production thousand short tons | 686 | 798 | 704 | 800 | 839 |
| Sales by producers do | 757 | 769 | 725 | 814 | 882 |
| Bulk do | 276 | 259 | 223 | 373 | 396 |
| Packaged do | 481 | 511 | 503 | 441 | 486 |
| Value of sales thousands | $18,784 | $16,871 | $18,667 | $19,907 | $21,892 |
| Average per short ton | $24.82 | $21.94 | $25.73 | $24.47 | $24.81 |
| Average per short ton, bulk | $17.28 | $16.34 | $18.34 | $20.47 | $20.29 |
| Average per short ton, packaged or baled | $29.14 | $24.77 | $29.00 | $27.85 | $28.49 |
| Imports for consumption thousand short tons | 342 | 370 | 419 | 485 | 477 |
| Consumption, apparent[1] do | 1,089 | 1,080 | 1,042 | 1,146 | 1,255 |
| Stocks, yearend producers' do | 269 | 357 | 438 | 577 | 638 |
| World: Production do | [r]276,267 | [r]283,504 | 282,266 | [p]282,719 | [e]283,106 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Apparent consumption equals U.S. primary production plus imports minus exports plus adjustments for industry stock changes.

## DOMESTIC PRODUCTION

Peat was produced by 99 active domestic operations. There were 11 large operations with capacities greater than 25,000 tons per year—4 reed-sedge operations and 1 humus operation in Michigan, 4 reed-sedge operations in Florida, 1 reed-sedge operation in Illinois, and 1 humus operation in Colorado—that accounted for 53% of production, compared with 41% in 1984. Reed-sedge production increased from 68% in 1984 to greater than 72% of total output in 1985. Humus accounted for 22%; hypnum, 3%; sphagnum, 2%; and unclassified, less than 1%. About 11,000 tons of peat was produced for use as a fuel to generate thermal energy for a lumber company and for peat fuel test burns.

**Table 2.—Relative size of peat operations in the United States**

| Size in short tons per year | Active operations | | Production (thousand short tons) | |
|---|---|---|---|---|
| | 1984 | 1985 | 1984 | 1985 |
| 25,000 and over | 8 | 11 | 329 | 446 |
| 15,000 to 24,999 | 7 | 7 | 187 | 116 |
| 10,000 to 14,999 | 11 | 7 | 131 | 84 |
| 5,000 to 9,999 | 14 | 17 | 97 | 115 |
| 2,000 to 4,999 | 25 | 15 | 81 | 48 |
| 1,000 to 1,999 | 13 | 15 | 18 | 21 |
| Under 1,000 | 23 | 27 | 6 | 10 |
| Total[1] | 101 | 99 | 800 | 839 |

[1] Data may not add to totals shown because of independent rounding.

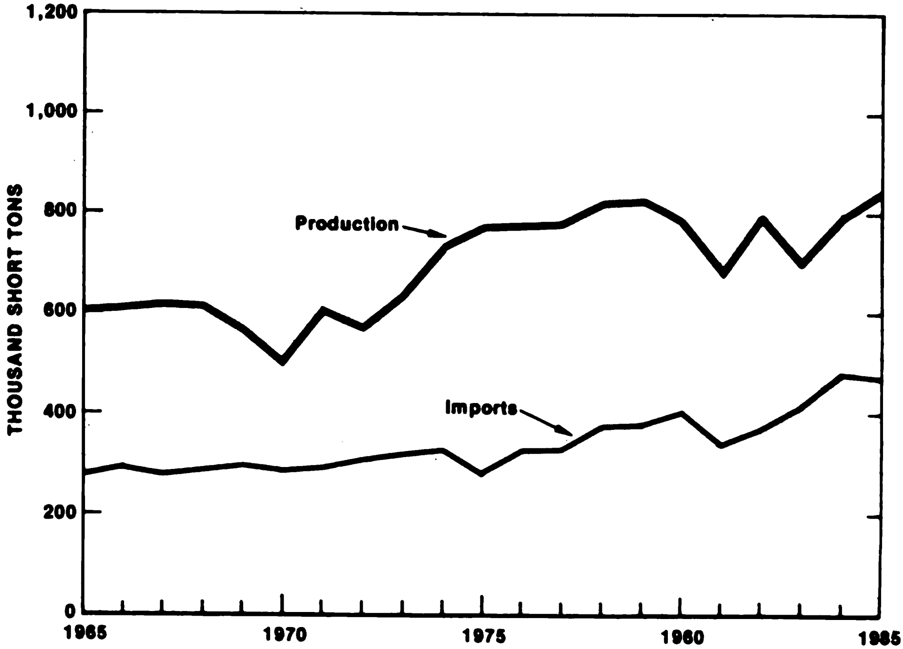

Figure 1.—Production and imports of peat in the United States.

## CONSUMPTION AND USES

U.S. peat producers' domestic sales increased slightly and consisted of 73% reed-sedge, 20% humus, 3% hypnum, 3% sphagnum, and 1% unclassified. Sales of both bulk peat and packaged peat increased. Sales of bagged or baled peat were 55% of total sales and consisted of 83% reed-sedge, 8% humus, 5% hypnum, and 4% sphagnum. Peat sales increased for general soil improvement, golf courses, mixed fertilizers, nurseries, vegetable growing, and other uses. Sales decreased for peat used as an earthworm culture medium, an ingredient for potting soils, in mushroom beds, for packing flowers, and as a seed inoculant. Apparent consumption of peat increased as a result of an increase in demand.

**Table 3.—U.S. peat sales by producers in 1985, by use**

| Use | In bulk | | In packages | | Total[1] | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Earthworm culture medium | 1,775 | $34 | 112 | $2 | 1,887 | $36 |
| General soil improvement | 127,820 | 1,897 | 452,999 | 11,137 | 580,819 | 13,034 |
| Golf courses | 30,199 | 815 | -- | -- | 30,199 | 815 |
| Ingredient for potting soils | 99,423 | 2,437 | 18,765 | 831 | 118,188 | 3,268 |
| Mixed fertilizers | 15,535 | 167 | -- | -- | 15,535 | 167 |
| Mushroom beds | 3,831 | 64 | -- | -- | 3,831 | 64 |
| Nurseries | 100,852 | 2,198 | 4,118 | 280 | 104,970 | 2,477 |
| Packing flowers, plants, shrubs, etc | 1,030 | 14 | -- | -- | 1,030 | 14 |
| Seed inoculant | 352 | 119 | 3,935 | 1,308 | 4,287 | 1,427 |
| Vegetable growing | 3,691 | 59 | 9 | ([2]) | 3,700 | 59 |
| Other | 11,478 | 229 | 6,480 | 300 | 17,958 | 529 |
| Total | 395,986 | 8,033 | 486,418 | 13,858 | 882,404 | [1]21,892 |

[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.

**Table 4.—U.S. peat production and sales by producers in 1985, by State**

| State | Active operations | Production | Sales | | |
|---|---|---|---|---|---|
| | | Quantity (thousand short tons) | Quantity (thousand short tons) | Value[1] (thousands) | Percent packaged |
| California | 2 | W | W | W | 92 |
| Colorado | 4 | W | W | W | 84 |
| Florida | 13 | 263 | 248 | $5,838 | 18 |
| Georgia | 2 | W | W | W | 98 |
| Illinois | 5 | W | W | W | 93 |
| Indiana | 6 | 38 | 54 | W | 76 |
| Iowa | 4 | 12 | 11 | 415 | 28 |
| Maine | 1 | W | -- | -- | -- |
| Maryland | 1 | W | W | W | 14 |
| Massachusetts | 1 | W | W | W | 10 |
| Michigan | 17 | 243 | 282 | 5,414 | 72 |
| Minnesota | 5 | 27 | 34 | 1,720 | 63 |
| Montana | 2 | W | W | W | 100 |
| New Jersey | 5 | W | W | 811 | 86 |
| New York | 5 | W | W | W | 91 |
| North Carolina | 3 | W | W | W | 77 |
| North Dakota | 1 | W | W | W | 88 |
| Ohio | 7 | 12 | 16 | 418 | 56 |
| Pennsylvania | 7 | 20 | 21 | 602 | 26 |
| South Carolina | 1 | W | W | 178 | 36 |
| Washington | 3 | 12 | 12 | 292 | -- |
| Wisconsin | 4 | W | 10 | W | 83 |
| Total[2] or average | 99 | 839 | 882 | 21,892 | 55 |

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1] Values are f.o.b. producing plant.
[2] Data may not add to totals shown because of independent rounding.

## Table 5.—U.S. peat sales by producers in 1985, by use

| Use | Sphagnum moss | | | Hypnum moss | | | Reed-sedge | | |
|---|---|---|---|---|---|---|---|---|---|
| | Quantity | | Value (thousands) | Quantity | | Value (thousands) | Quantity | | Value (thousands) |
| | Weight (short tons) | Volume[1] (cubic yards) | | Weight (short tons) | Volume (cubic yards) | | Weight (short tons) | Volume (cubic yards) | |
| Earthworm culture medium | 450 | 1,500 | $13 | -- | -- | -- | 1,017 | 1,922 | $19 |
| General soil improvement | 21,398 | 127,282 | 1,335 | 20,508 | 51,768 | $743 | 431,536 | 879,225 | 9,507 |
| Golf courses | 780 | 2,600 | 22 | 500 | 1,000 | 7 | 19,027 | 39,692 | 577 |
| Ingredient for potting soils | 1,845 | 4,482 | 27 | -- | -- | -- | 79,413 | 168,487 | 2,590 |
| Mixed fertilizers | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Mushroom beds | -- | -- | -- | 600 | 2,000 | 30 | 3,231 | 6,175 | 34 |
| Nurseries | 105 | 350 | 2 | 4,238 | 17,500 | 290 | 88,269 | 181,487 | 2,004 |
| Packing flowers, plants, shrubs, etc | 120 | 400 | 2 | -- | -- | -- | 110 | 200 | 1 |
| Seed inoculant | -- | -- | -- | -- | -- | -- | 3,841 | 6,984 | 1,248 |
| Vegetable growing | -- | -- | -- | -- | -- | -- | 3,055 | 6,079 | 50 |
| Other | -- | -- | -- | -- | -- | -- | 15,480 | 42,000 | 500 |
| Total[2] | 24,698 | 136,614 | 1,402 | 25,846 | 72,268 | 1,069 | 644,979 | 1,332,251 | 16,530 |
| | Humus | | | Other | | | Total[2] | | |
| | Quantity | | Value (thousands) | Quantity | | Value (thousands) | Quantity | | Value (thousands) |
| | Weight (short tons) | Volume (cubic yards) | | Weight (short tons) | Volume (cubic yards) | | Weight (short tons) | Volume (cubic yards) | |
| Earthworm culture medium | 420 | 740 | $4 | -- | -- | -- | 1,887 | 4,162 | $36 |
| General soil improvement | 104,027 | 151,770 | 1,409 | 2,850 | 6,000 | $40 | 580,819 | 1,216,045 | 13,034 |
| Golf courses | 9,892 | 18,965 | 210 | -- | -- | -- | 30,199 | 62,257 | 815 |
| Ingredient for potting soils | 37,430 | 73,018 | 652 | -- | -- | -- | 118,188 | 245,987 | 3,268 |
| Mixed fertilizers | 15,535 | 23,900 | 167 | -- | -- | -- | 15,535 | 23,900 | 167 |
| Mushroom beds | -- | -- | -- | -- | -- | -- | 3,831 | 8,175 | 64 |
| Nurseries | 11,858 | 23,815 | 172 | 500 | 1,000 | 10 | 104,970 | 223,652 | 2,477 |
| Packing flowers, plants, shrubs, etc | 800 | 1,500 | 10 | -- | -- | -- | 1,030 | 2,100 | 14 |
| Seed inoculant | 446 | 595 | 178 | -- | -- | -- | 4,287 | 7,579 | 1,427 |
| Vegetable growing | 645 | 1,263 | 9 | -- | -- | -- | 3,700 | 7,342 | 59 |
| Other | 38 | 50 | (3) | 2,440 | 5,648 | 29 | 17,958 | 47,698 | 529 |
| Total[2] | 181,091 | 295,116 | 2,811 | 5,790 | 12,648 | 79 | 882,404 | 1,848,897 | 21,892 |

[1] Volume of nearly all sphagnum moss was measured after compaction and packaging.
[2] Data may not add to totals shown because of independent rounding.
[3] Less than 1/2 unit.

Table 6.—U.S. peat production and producers' yearend stocks in 1985, by kind

| Kind | Active operations | Production (short tons) | Percent of production | Yearend stocks (short tons) |
|---|---|---|---|---|
| Sphagnum moss | 5 | 15,840 | 1.9 | 10,679 |
| Hypnum moss | 6 | 28,277 | 3.4 | 10,621 |
| Reed-sedge | 55 | 608,118 | 72.5 | 553,167 |
| Humus | 29 | 184,123 | 21.9 | 85,545 |
| Other | 4 | 2,610 | .3 | 28,800 |
| Total | 99 | 838,968 | 100.0 | 688,812 |

## PRICES AND SPECIFICATIONS

The average reported price per ton for all types of peat, f.o.b. plant, increased slightly. The unit price for bulk peat decreased slightly, and that for packaged peat increased somewhat. The price per ton of imported sphagnum peat increased a small amount.

Table 7.—Prices[1] for peat in 1985

(Dollars per unit)

| | Sphagnum moss | Hypnum moss | Reed-sedge | Humus | Other | Average |
|---|---|---|---|---|---|---|
| Domestic: | | | | | | |
| Bulk: | | | | | | |
| Per short ton | 20.48 | 36.90 | 24.20 | 13.73 | 13.64 | 20.29 |
| Per cubic yard | 8.93 | 12.81 | 11.63 | 8.26 | 6.24 | 10.45 |
| Packaged or baled: | | | | | | |
| Per short ton | 77.78 | 41.91 | 26.45 | 22.13 | -- | 28.49 |
| Per cubic yard | 10.50 | 15.05 | 12.86 | 14.66 | -- | 12.83 |
| Average: | | | | | | |
| Per short ton | 56.77 | 41.36 | 25.63 | 15.52 | 13.64 | 24.81 |
| Per cubic yard | 10.26 | 14.79 | 12.41 | 9.53 | 6.24 | 11.84 |
| Imported, total, per short ton[2] | 121.18 | XX | XX | XX | XX | 121.18 |

XX Not applicable.
[1] Prices are f.o.b. plant.
[2] Average customs price.

Table 8.—Average density of domestic peat sold in 1985

(Pounds per cubic yard)

| | Sphagnum moss | Hypnum moss | Reed-sedge | Humus | Other |
|---|---|---|---|---|---|
| Bulk | 873 | 694 | 961 | 1,203 | 916 |
| Packaged | 270 | 718 | 972 | 1,325 | -- |
| Bulk and packaged | 362 | 715 | 968 | 1,227 | 916 |

## FOREIGN TRADE

Peat imports for domestic consumption decreased slightly in quantity and increased slightly in value. More than 99% of the imports was sphagnum moss peat from Canada. Canadian sphagnum moss peat was in demand because of consumer loyalty to brand and because in most areas domestic sphagnum moss peat had not entered the U.S. retail market. Almost 42% of the imported peat entered the United States through customs districts in New York. Large quantities also entered through customs districts in Maine, Michigan, Montana, North Dakota, Vermont, and Washington. Minor quantities of peat were imported from the Federal Republic of Germany, Mexico, and the Netherlands.

### Table 9.—U.S. imports for consumption of peat moss in 1985, by country

| Country | Poultry- and stable-grade |  | Fertilizer-grade |  | Total |  |
|---|---|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Canada | 25,174 | $3,559 | 451,612 | $54,207 | 476,786 | $57,766 |
| Germany, Federal Republic of | -- | -- | 51 | 4 | 51 | 4 |
| Mexico | 107 | 30 | -- | -- | 107 | 30 |
| Netherlands | 16 | 2 | 110 | 6 | 126 | 8 |
| Other[1] | 78 | 15 | 245 | 27 | 318 | 42 |
| Total | 25,370 | 3,606 | 452,018 | 54,244 | 477,388 | 57,850 |

[1] Includes China, Denmark, Finland, France, Guatemala, Ireland, Japan, Kiribati, Morocco, New Caledonia, Panama, Sweden, the U.S.S.R., and the United Kingdom.

Source: Bureau of the Census.

### Table 10.—U.S. imports for consumption of peat moss in 1985, by customs district

| Customs district | Poultry- and stable-grade |  | Fertilizer-grade |  | Total[1] |  |
|---|---|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Boston, MA | 36 | $2 | -- | -- | 36 | $2 |
| Buffalo, NY[2] | 15,860 | 2,474 | 13,417 | $1,676 | 29,277 | 4,151 |
| Chicago, IL | 25 | 2 | -- | -- | 25 | 2 |
| Detroit, MI[2] | 8,712 | 992 | 39,882 | 4,787 | 48,594 | 5,778 |
| Duluth, MN[2] | -- | -- | 1,110 | 160 | 1,110 | 160 |
| Great Falls, MT[2] | -- | -- | 53,976 | 8,488 | 53,976 | 8,488 |
| Houston, TX | 24 | 3 | -- | -- | 24 | 3 |
| Laredo, TX | 108 | 30 | -- | -- | 108 | 30 |
| Los Angeles, CA | -- | -- | 34 | 3 | 34 | 3 |
| New Orleans, LA[2] | -- | -- | 20 | 4 | 20 | 4 |
| New York, NY | 10 | 6 | 127 | 9 | 137 | 15 |
| Norfolk, VA[2] | 16 | 2 | 44 | 6 | 60 | 8 |
| Ogdensburg, NY[2] | 262 | 33 | 169,122 | 16,974 | 169,384 | 17,006 |
| Pembina, ND | 22 | 2 | 93,866 | 12,143 | 93,888 | 12,145 |
| Philadelphia, PA[2] | -- | -- | 121 | 21 | 121 | 21 |
| Portland, ME[2] | 129 | 22 | 34,074 | 3,750 | 34,203 | 3,772 |
| St. Albans, VT[2] | 22 | 6 | 27,648 | 3,037 | 27,670 | 3,043 |
| San Francisco, CA | -- | -- | 84 | 12 | 84 | 12 |
| San Juan, PR[2] | 34 | 7 | -- | -- | 34 | 7 |
| Seattle, WA[2] | 91 | 21 | 18,493 | 3,175 | 18,584 | 3,197 |
| Virgin Islands | 19 | 5 | -- | -- | 19 | 5 |
| Total[1] | 25,370 | 3,606 | 452,018 | 54,244 | 477,388 | 57,850 |

[1] Data may not add to totals shown because of independent rounding.
[2] Predominantly of Canadian origin.

Source: Bureau of the Census.

## WORLD REVIEW

**China.**—An exploration team from the Chinese Academy of Sciences discovered deposits in central China containing an estimated 7 billion cubic meters of peat. Production from these deposits was expected to be used as fertilizer and fuel. The deposits were located on the Qingzang plateau at the juncture of the Gansu Quinghai, and Sichuan Provinces.[2]

**Finland.**—Vapo Oy, a Finnish company specializing in peat production and development worldwide, purchased Peatrex Ltd., a peat producing company in Minnesota. Vapo Oy supplied machinery and technical expertise to peat projects in Africa, Finland, Southeast Asia, Sweden, and Western Europe.[3]

Kemira Oy, a state-owned company, planned to build a new 80,000-ton-per-year ammonia plant that would use peat for feedstock. The plant was to be located at Oulu and employ over 250 people in the production and handling of the peat.[4]

**Table 11.—Peat: World production, by country[1]**

(Thousand short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984$^{p}$ | 1985$^{e}$ |
|---|---|---|---|---|---|
| Argentina: Agricultural use | 3 | 4 | 4 | 3 | 3 |
| Australia$^{e}$ | $^{r}$17 | $^{r}$18 | $^{r}$13 | 15 | 15 |
| Burundi | 10 | 15 | 15 | 15 | 15 |
| Canada: Agricultural use | 509 | 537 | 583 | $^{e}$550 | 550 |
| Denmark: Agricultural use[3] | 36 | $^{r}$40 | $^{r\ e}$37 | 34 | 40 |
| Finland: | | | | | |
| Agricultural use | 225 | 637 | 303 | 248 | 220 |
| Fuel | 1,436 | 6,063 | 3,698 | 2,991 | 3,300 |
| France: Agricultural use$^{e}$ | 143 | 132 | 121 | $^{r}$250 | 220 |
| Germany, Federal Republic of: | | | | | |
| Agricultural use | 1,920 | 2,030 | 2,059 | 1,575 | 2,000 |
| Fuel | 271 | 279 | 285 | 305 | 290 |
| Hungary: Agricultural use$^{e}$ | 77 | 77 | 77 | 77 | 77 |
| Ireland: | | | | | |
| Agricultural use | 89 | 105 | $^{e}$105 | 106 | 105 |
| Fuel | 5,906 | 5,819 | $^{r\ e}$7,330 | 8,746 | 8,430 |
| Israel: Agricultural use$^{e}$ | 22 | 22 | 22 | 22 | 22 |
| Netherlands$^{e}$ | 441 | 441 | 441 | 496 | 500 |
| Norway:$^{e}$ | | | | | |
| Agricultural use | 66 | 66 | 66 | 66 | 66 |
| Fuel | 1 | 1 | 1 | 1 | 1 |
| Poland: Fuel and agricultural use$^{e}$ | [4]222 | 220 | 220 | 220 | 220 |
| Spain | 43 | 66 | 44 | 61 | 55 |
| Sweden: Agricultural use | 144 | $^{r}$139 | 138 | $^{e}$138 | 138 |
| U.S.S.R.: | | | | | |
| Agricultural use | $^{r}$193,000 | $^{r\ e}$200,000 | $^{r\ e}$200,000 | $^{r\ e}$200,000 | 200,000 |
| Fuel$^{e}$ | 66,000 | 66,000 | 66,000 | 66,000 | 66,000 |
| United States: | | | | | |
| Agricultural use | 686 | 798 | 703 | 789 | [4]828 |
| Fuel | -- | -- | 1 | 11 | [4]11 |
| Total | $^{r}$276,267 | $^{r}$283,504 | 282,266 | 282,719 | 283,106 |
| Fuel peat included in total | 73,836 | 78,382 | 77,535 | 78,274 | 78,252 |

$^{e}$Estimated. $^{p}$Preliminary. $^{r}$Revised.

[1] Table includes data available through June 10, 1986.

[2] In addition to the countries listed, Austria, Iceland, and Italy produce negligible quantities of fuel peat, the German Democratic Republic is a major producer, and Venezuela produces small amounts of peat for agricultural use, but output is not officially reported, and available information is inadequate for formulation of reliable estimates of output levels.

[3] Sales.

[4] Reported figure.

## TECHNOLOGY

Swedish researchers seeking to utilize peat as an organic raw material for chemicals determined that peat contains an enormously complex mixture of organic materials. The largest fractions are lignins, humic acids, hemicelluloses, celluloses, and bitumens.[5]

Research into the use of oxidatively solubilized coal (OSC) in alcohol to produce a diesel-like fuel determined that peat was also good feedstock for the process. Solutions of peat-derived OSC in methanol, containing as much as 50% by weight of the OSC, were similar to conventional diesel fuel in viscosity, lubricity, and cetane value. The combustion product was essentially smoke free and low in nitrogen oxides. The OSC derived from peat outperformed OSC made from some kinds of coal.[6]

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[1] Physical scientist, Division of Industrial Minerals.

[2] Mining Magazine. China Peat Discovery. V. 152, No. 4, April 1985, p. 287.

[3] News—Tribune and Herald (Duluth, MN). Peatrex Sale to Finnish Firm Expected To End Controversy. Sept. 28, 1985.

[4] Fertilizer International. No. 213, 1985, p. 6.

[5] Foersvarets Forskningsanstalt, Umea (Sweden). Peat as a Raw Material for Chemicals. Aug. 1985, 31 pp.

[6] Chemical & Engineering News. Process Yields Diesel-Like Fuel From Coal, Peat, Biomass. V. 63, No. 26, July 1, 1985, p. 23.

# Perlite

## By A. C. Meisinger[1]

U.S. production of both processed and expanded perlite increased slightly in 1985. Processed perlite sold and used was 507,000 short tons valued at $17.2 million. Expanded perlite sold and used was 459,000 tons valued at $81 million. Imports of processed perlite from Greece continued to increase and were 52,000 tons compared with 46,000 tons (revised) in 1984. Construction-related uses continued to dominate the domestic market for expanded perlite with nearly 69% of total sales.

**Domestic Data Coverage.**—Domestic production data for perlite are developed by the Bureau of Mines from two separate voluntary surveys, one for domestic mine operations and the other for plant operations. Of the 12 mining operations to which a request was sent, 9, or 75%, responded, representing 90% of the total processed ore sold and used shown in table 1. Mine data for the three nonrespondents were estimated using reported prior year production levels adjusted by trends in employment and other guidelines. Of the 65 expanding plants to which a request was sent, 64 plants were active; of these, 43 plants, or 67%, responded, representing 82% of the total expanded perlite sold and used shown in table 1. Plant data for the 21 nonrespondents were estimated using reported prior year production levels adjusted by trends in employment and other guidelines.

**Table 1.—Perlite mined, processed, expanded, and sold and used by producers in the United States**

(Thousand short tons and thousand dollars)

| Year | Perlite mined[1] | Processed perlite: Sold to expanders: Quantity | Processed perlite: Sold to expanders: Value | Processed perlite: Used at own plant to make expanded material: Quantity | Processed perlite: Used at own plant to make expanded material: Value | Processed perlite: Total quantity sold and used | Expanded perlite: Quantity produced | Expanded perlite: Sold and used: Quantity | Expanded perlite: Sold and used: Value |
|---|---|---|---|---|---|---|---|---|---|
| 1981 | 710 | 324 | 9,928 | 267 | 7,530 | 591 | 494 | 485 | 66,300 |
| 1982 | 623 | 263 | 8,755 | 243 | 7,289 | 506 | 433 | 428 | 63,600 |
| 1983 | 608 | 293 | 9,942 | 181 | 5,722 | 474 | 387 | 385 | 63,500 |
| 1984 | 653 | 310 | 10,395 | 188 | 6,243 | 498 | [r]440 | [r]439 | [r]74,000 |
| 1985 | 678 | 316 | 10,957 | 191 | 6,203 | 507 | 461 | 459 | 81,000 |

[r] Revised.

[1] Crude ore mined and stockpiled for processing.

## DOMESTIC PRODUCTION

**Processed Perlite.**—The quantity of perlite mined for processing, by 10 companies from 12 operations in 5 Western States, was 678,000 tons, a slight increase over that of 1984. Of that total, five mines in New Mexico accounted for 86%. The remaining 14% was mined in Arizona, California, Colorado, and Nevada.

Production of processed perlite increased slightly to 507,000 tons sold and used valued at $17.2 million compared with 1984 production of 498,000 tons and $16.6 million. New Mexico mines accounted for 83% of the U.S. total processed perlite sold and used. Ore producers were Harborlite Corp. and Sil-Flo Inc. in Arizona; American Perlite Co. in

California; Persolite Products Inc. in Colorado; Oneida Perlite Corp. in Idaho; Delamar Perlite Co. and U.S.G. Corp. (formerly United States Gypsum Co.) in Nevada; and Grefco Inc., Manville Products Corp., Silbrico Corp., and U.S.G. in New Mexico.

**Expanded Perlite.**—Expanded perlite was produced by 64 plants in 31 States. The quantity produced increased 5% (revised) over that produced in 1984. Leading States, in descending order of sales, were Mississippi, Pennsylvania, California, Georgia, Illinois, Kentucky, Texas, Florida, Virginia, Indiana, and Colorado. California and Texas each had seven active plants, followed by Pennsylvania with five, and Florida and Indiana with four each.

### Table 2.—Expanded perlite produced and sold and used by producers in the United States, by State

| State | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Quantity produced (short tons) | Sold and used | | | Quantity produced (short tons) | Sold and used | | |
| | | Quantity (short tons) | Value (thousands) | Average value per ton[1] | | Quantity (short tons) | Value (thousands) | Average value per ton[1] |
| Arkansas | 1,100 | 1,100 | W | W | W | W | W | W |
| California | 48,100 | 47,500 | $^{r}$$8,574 | $^{r}$$181 | 47,300 | 46,300 | $8,516 | $184 |
| Florida | 20,600 | 20,500 | 3,470 | 169 | 26,400 | 26,400 | 4,831 | 183 |
| Indiana | 22,500 | 22,200 | 4,982 | 225 | 22,200 | 22,300 | 5,501 | 247 |
| Kansas | W | W | W | W | 800 | 800 | 200 | 250 |
| Massachusetts | 2,400 | 2,300 | 779 | 339 | 2,300 | 2,200 | 708 | 322 |
| Pennsylvania | $^{r}$42,000 | $^{r}$42,000 | $^{r}$7,078 | $^{r}$169 | 48,300 | 48,100 | 8,260 | 172 |
| Texas | 27,200 | 27,100 | 5,805 | 214 | 27,900 | 27,400 | 5,915 | 216 |
| Wisconsin | W | W | W | W | 1,200 | 1,200 | 296 | 250 |
| Other[2] | $^{r}$275,700 | $^{r}$275,900 | $^{r}$43,610 | $^{r}$158 | 284,600 | 283,900 | 46,800 | 165 |
| Total[3] | $^{r}$440,000 | $^{r}$439,000 | $^{r}$74,000 | $^{r}$169 | 461,000 | 459,000 | 81,000 | 177 |

$^{r}$Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Average value based on unrounded data and rounded to nearest dollar.

[2] Includes Alabama, Arizona, Colorado, Georgia, Idaho, Illinois, Iowa, Kentucky, Louisiana, Maine, Michigan, Minnesota (1984), Mississippi, Missouri, Nevada, New Jersey, New York, North Carolina, Oregon, Tennessee, Utah, Virginia, Wyoming, and items indicated by symbol W.

[3] Data may not add to totals shown because of independent rounding.

## CONSUMPTION AND USES

Apparent domestic consumption of processed perlite was 539,000 tons compared with 524,000 tons in 1984. Domestic consumption of expanded perlite increased 5% to 459,000 tons. Construction-related uses, such as aggregates for concrete, plaster, formed products, and loose-fill insulation, continued to account for two-thirds of sales. All major end uses but plaster aggregates and low-temperature insulation increased in sales during the year.

### Table 3.—Expanded perlite sold and used by producers in the United States, by use

(Short tons)

| Use | 1984 | 1985 |
|---|---|---|
| Concrete aggregate | 20,800 | 21,400 |
| Fillers | 12,100 | 16,800 |
| Filter aid | 60,600 | 62,400 |
| Formed products[1] | $^{r}$257,000 | 267,300 |
| Horticultural aggregate[2] | 36,100 | 39,600 |
| Low-temperature insulation | 5,000 | 4,100 |
| Masonry and cavity-fill insulation | 15,100 | 15,200 |
| Plaster aggregate | $^{r}$12,700 | 11,300 |
| Other[3] | 19,100 | 20,600 |
| Total[4] | $^{r}$439,000 | 459,000 |

$^{r}$Revised.

[1] Includes acoustic ceiling tile, pipe insulation, roof insulation board, and unspecified formed products.

[2] Includes fertilizer carriers.

[3] Includes fines, high-temperature insulation, paint texturizer, refractories, and various nonspecified industrial uses.

[4] Data may not add to totals shown because of independent rounding.

## PRICES

The average price of processed perlite sold to expanders increased slightly from $33.53 per ton to $34.67 per ton, but the average price of processed perlite used by producers in their own plants declined from $33.21 per ton to $32.48 per ton in 1985. The average value of all processed perlite sold and used was $33.85 per ton, a slight increase over that of 1984. The value of expanded perlite sold and used averaged $177 per ton compared with $169 per ton (revised) in 1984.

## FOREIGN TRADE

The United States imported approximately 52,000 tons of processed perlite from Greece, compared with 46,000 tons (revised) in 1984. Exports of processed perlite were estimated to be 20,000 tons to Canada, the same as those of 1984.

## WORLD REVIEW

Estimated world production of perlite totaled nearly 1.8 million tons in 1985, a slight decrease from that of 1984. Three countries, Greece, the U.S.S.R., and the United States, accounted for 76% of the world total.

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[1] Industry economist, Division of Industrial Minerals.

**Table 4.—Perlite: World production, by country[1]**

(Thousand short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Australia[3] | 2 | 1 | 2 | [e]2 | 2 |
| Czechoslovakia | 47 | 50 | 49 | [e]49 | 49 |
| Greece | 145 | 167 | 167 | 196 | 195 |
| Hungary[3] | 105 | 99 | 103 | 113 | 112 |
| Italy[e] | 94 | 88 | 83 | [r]88 | 88 |
| Japan[e] | 83 | 83 | 83 | 83 | 83 |
| Mexico[3] | 63 | 36 | 46 | 35 | 33 |
| New Zealand[3] | 1 | 2 | 1 | ([4]) | -- |
| Philippines | 8 | 4 | 2 | 17 | 3 |
| Turkey | 50 | 134 | 32 | 67 | 66 |
| U.S.S.R.[e] | [r]660 | [r]660 | [r]660 | [r]660 | 660 |
| United States (processed ore sold and used by producers) | 591 | 506 | 474 | 498 | [5]507 |
| Total | [r]1,849 | [r]1,830 | 1,702 | 1,808 | 1,798 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Unless otherwise specified, figures represent processed ore output. Table includes data available through June 3, 1986.

[2] In addition to the countries listed, Algeria, Bulgaria, China, Iceland, Mozambique, the Republic of South Africa, and Yugoslavia are believed to have produced perlite but output data are not reported and available information is inadequate for formulation of reliable estimates of output levels.

[3] Crude ore.

[4] Revised to zero.

[5] Reported figure.

# Phosphate Rock

## By William F. Stowasser[1]

Phosphate rock production marginally increased in 1985 but the depressed state of the U.S. agricultural sector limited demand for phosphate fertilizer raw materials. However, the export market for phosphate fertilizer was exceptionally strong. Sales of diammonium phosphate, for example, were a record high 7.2 million metric tons, with prices frequently below production costs. Without the export market, phosphate fertilizer producers' financial status would have been substantially weaker.

Phosphate rock inventories increased during the year as demand declined. Phosphate producing companies closed several mines and plants for an indefinite time: Some were for sale, some temporarily closed to reduce inventories, several filed for reorganization under chapter 11 of the Federal Bankruptcy Act, and some merged to reduce financial losses. Despite the restructuring of the phosphate industry, demand and supply were still out of balance. The plant shutdowns and curtailed production failed to reduce the phosphate surplus; inventory levels increased, prices were cut, and profitability was reduced for phosphate rock and phosphate fertilizer.

Electric furnaces traditionally have been used to smelt phosphate rock to produce

**Table 1.—Salient phosphate rock statistics[1]**

(Thousand metric tons and thousand dollars unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Mine production (crude ore) | 183,733 | 104,135 | 125,691 | 163,012 | 175,058 |
| Marketable production | 53,624 | 37,414 | 42,573 | 49,197 | 50,835 |
| $P_2O_5$ content | 16,365 | 11,504 | 13,088 | 14,889 | 15,634 |
| Value | $1,437,986 | $950,326 | $1,021,095 | $1,182,244 | [2]$1,203,265 |
| Average per metric ton | [3]$26.82 | [3]$25.40 | [3]$23.98 | [3]$24.03 | [4]$23.67 |
| Sold or used by producers[5] | 45,526 | 38,571 | 46,839 | 53,277 | 46,634 |
| $P_2O_5$ content | 13,939 | 11,814 | 14,336 | 16,244 | 14,363 |
| Value | $1,212,433 | $983,465 | $1,122,966 | $1,278,356 | [2]$1,103,827 |
| Average per metric ton[4 6] | $26.63 | $25.50 | $23.97 | $23.99 | $23.67 |
| Exports[7] | 10,395 | 9,842 | 12,010 | 11,528 | 10,284 |
| $P_2O_5$ content | 3,300 | 3,138 | 3,839 | 3,646 | 3,263 |
| Value | $373,192 | $293,626 | $327,345 | $324,784 | [2]$281,515 |
| Average per metric ton[4] | $35.90 | $29.83 | $27.26 | $28.17 | $27.37 |
| Imports for consumption | 13 | 31 | 9 | [8]9 | [8]34 |
| C.i.f. value | $420 | $1,302 | $276 | $274 | $1,747 |
| Average per metric ton | $32.31 | $42.00 | $42.69 | $31.71 | [9]$51.54 |
| Consumption[10] | 35,144 | 28,760 | 34,838 | 41,758 | 36,384 |
| Stocks, Dec. 31: Producer | 19,619 | 18,287 | 14,500 | 11,897 | 15,534 |
| World: Production | [r]143,001 | [r]127,335 | 139,404 | [p]152,433 | [e]151,363 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Data for the same items appearing in this and other tables may not reconcile because of computer rounding.

[2]The total value is based on a weighted value.

[3]Arithmetic average of sold or used values.

[4]Computer calculated average value based on the weighted sold or used value.

[5]Includes domestic sales and exports.

[6]Weighted average of sold or used values.

[7]Exports reported to the Bureau of Mines by companies.

[8]Bureau of the Census data, excluding reported Canadian and Israeli imports.

[9]Average unit value obtained from unrounded data.

[10]Measured by sold or used plus imports minus exports.

elemental phosphorus ($P_4$). Most of the $P_4$, perhaps as much as 85%, was used to produce technical-grade phosphoric acid, as opposed to food-grade acid, which was then used to manufacture numerous phosphate salts. U.S. production of $P_4$ declined from a peak of 560,000 tons in 1969 to 370,000 tons in 1984. Overcapacity in this segment of the phosphate industry was comparable to that of the fertilizer industry. A new, significantly lower cost, wet acid process was used in Europe, Israel, and Japan to produce technical-grade phosphoric acid. Some of this acid was exported directly to the United States or converted into phosphate salts and exported. The decline in demand for U.S.-produced $P_4$ was attributed to the high cost of the thermal process, increased competition from foreign imports, and a nationwide campaign to prohibit phosphates in detergent products.

**Domestic Data Coverage.**—Domestic production data for phosphate rock are developed by the Bureau of Mines from two separate, voluntary surveys of U.S. operations. Typical of these surveys is the semiannual "Phosphate Rock Survey." Of the 24 operations to which a survey request was sent, all responded, representing 100% of the U.S. production data shown in table 1.

**Legislation and Government Programs.**—The Food Security Act of 1985 was expected to expand the potential for grain exports by reducing U.S. grain prices on world markets and supporting farm income by maintaining target prices at current levels over the next 2 years. The farm program also placed a 20% and 25% nonpaid acreage reduction maximum on the U.S. Department of Agriculture for corn and wheat, respectively, in 1986. This implied a smaller reduction in acreage in the spring of 1986 than had been anticipated.

## DOMESTIC PRODUCTION

Florida and North Carolina produced about 6% more marketable phosphate rock than the 42.5 million tons produced in 1984. The Western States and Tennessee produced somewhat less than that produced in 1984.

**Florida and North Carolina.**—Companies that mined phosphate rock in central Florida were Agrico Chemical Co., Beker Phosphate Inc., Brewster Phosphates, CF Industries Inc., Estech Inc., Gardinier Inc., W. R. Grace & Co., Hopewell Land Corp., International Minerals & Chemical Corp. (IMC), Mobil Mining and Minerals Co., and USS Agri-Chemicals Inc. Occidental Chemical Agricultural Products Inc. produced phosphate rock in Hamilton County, north Florida.

Several small companies in north-central Florida recovered soft phosphate rock from tailing ponds remaining from old inactive hard-rock phosphate rock mines. The estimated combined annual capacity of 45,000 tons has seldom been achieved. The soft rock was sold as an animal feed supplement.

In North Carolina, Texasgulf Chemicals Co., a subsidiary of Société Nationale Elf Aquitaine, operated the Lee Creek Mine near Aurora. North Carolina Phosphate Corp., an Agrico mining company, sold its reserves and assets to Texasgulf. Agrico, a Williams Co. subsidiary, received 15% of Texasgulf's stock and a warrant to purchase up to an additional 4.9%. The merger, subject to Government antitrust review, was expected to be completed by yearend. Texasgulf was the only phosphate mining company producing in North Carolina.

After divesting its North Carolina phosphate reserves and assets, Agrico operated three phosphate rock mines in central Florida until April, when the Saddle Creek Mine was closed. The Payne Creek and Fort Green Mines continued to operate throughout the year. The Payne Creek Mine's reserves were expected to permit operation for another 2 years.

AMAX Phosphate Inc.'s Big Four Mine remained closed during the year. AMAX Inc. wrote down the value of its fertilizer business and was attempting to sell the assets of AMAX Phosphate.

Beker announced in October that it had filed for reorganization under chapter 11 of the Federal Bankruptcy Code. Beker was unable to convince holders of its debt to exchange their debentures for new debentures and common stock. Throughout this period of adversity, Beker continued to produce phosphate rock at its Wingate Creek Mine.

Brewster, a partnership of American Cyanamid Co., 75%, and Kerr-McGee Corp., 25%, operated the Haynsworth and Lonesome Mines in Polk and Hillsborough Counties, respectively. American Cyanamid, Kerr-McGee, and IMC reached an agreement in principle, subject to approval of their respective boards of directors and customary regulatory agencies, to lease the Haynsworth and Lonesome beneficiation plants. Remaining phosphate rock reserves at the two mines were to be mined under a royalty agreement.

CF Industries operated the Hardee Phosphate Complex I Mine at Fort Green to supply phosphate rock for its chemical complex at Bartow and Plant City, FL. The Hardee Complex II Mine was deferred, and the Complex I Mine expansion plans were also deferred.

At the beginning of the year, W. R. Grace and IMC opened the Four Corners Mine at the intersections of Polk, Hardee, Manatee, and Hillsborough Counties, FL. The design capacity of the mine, with three draglines, was 5.5 million tons per year. W. R. Grace also operated the Hookers Prairie Mine, south of Mulberry, in Polk County, FL, and purchased 14.5 million tons of phosphate rock reserves from Agrico.

Estech, an Esmark Inc. subsidiary, had divested many of its Florida phosphate rock properties in 1983 and 1984. In 1985, Estech's retail fertilizer division was sold and the company was left with the closed Silver City Mine and one-third ownership in the active Watson Mine. Indications were that Estech's remaining assets would be put up for sale.

Early in the year, Gardinier filed for court protection under chapter 11 of the Federal Bankruptcy Act in order to reorganize its finances. The phosphate rock mine near Fort Meade, FL, and the fertilizer manufacturing complex south of Tampa, FL, operated throughout the year, with occasional shutdowns to adjust inventories. Cargill Inc., an international marketer and processor of agricultural and other bulk commodities, offered to purchase 80% of Gardinier in October. The agreement was finalized by yearend.

Hopewell opened a 500,000-ton-per-year phosphate rock mine near Lithia, FL, at the beginning of the year.

IMC, with 50% equity in the Four Corners Mine, operated the Clear Springs, Kingsford, and Noralyn-Phosphoria Mines in central Florida. At yearend, IMC agreed in principle to lease the Lonesome and Haynsworth phosphate rock beneficiation plants from American Cyanamid and Kerr-McGee, owners of Brewster Phosphates, and mine the reserves of these mines under a royalty agreement. The merger was subject to Federal Trade Commission approval.

Mobil operated the Nichols and Fort Meade Mines in central Florida. The Fort Meade reserves were expected to permit operation for only another 4 years at its current rate of production. Plans to construct a mine on Mobil's South Fort Meade deposit were deferred because of unfavorable economics.

USS Agri-Chemicals, a subsidiary of United States Steel Corp., operated the Rockland Mine with Freeport Phosphate Rock Co., a 50% partner. United States Steel announced that USS Agri-Chemicals was for sale. USS Agri-Chemicals sold fertilizer through retail centers and was a partner in a joint venture, Fort Meade Chemical Products, with W. R. Grace, in Fort Meade, FL.

Occidental operated two phosphate rock mines, Swift Creek and Suwannee River, in northern Florida. Occidental had capacity to produce 1.1 million tons per year of phosphoric acid from two plants and the capability to convert the acid to superphosphoric acid to supply liquid fertilizer plants in the U.S.S.R.

**Tennessee.**—Occidental, Monsanto Co., and Stauffer Chemical Co. mined and beneficiated phosphate rock from deposits in Giles, Hickman, Maury, and Williamson Counties. All of the phosphate rock was smelted in electric furnaces to produce $P_4$. Monsanto announced plans to close its $P_4$ plant in Columbia, TN, at the end of 1986 and to consolidate production at its Soda Springs, ID, electric-furnace plant. Chesebrough-Pond's Inc. purchased Stauffer in March 1985.

**Western States.**—Phosphate rock was mined in Idaho, Montana, and Utah for smelting in electric furnaces to produce $P_4$ and phosphate fertilizer.

Cominco American Incorporated operated the only underground mine in the country in Powell County, MT. After primary crushing, the ore was loaded into railroad cars for delivery to Kimberley, British Columbia, Canada.

Stauffer mined phosphate rock from the Wooley Valley Mine, northeast of Soda Springs, ID. The phosphate rock was shipped to Silver Bow, MT, to produce $P_4$.

The Conda Partnership, a 50-50 partnership between Beker and Western Co-operative Fertilizers Ltd., Calgary, Canada, mined phosphate rock from the Maybie Canyon Mine in Idaho. Part of the phosphate rock was exported to Canada for conversion to phosphate fertilizers, and Beker's share was beneficiated, calcined, and converted into phosphate fertilizers at Beker's fertilizer complex at Conda, ID. Production continued at the Maybie Canyon

Mine.

Chevron Resources Co. mined phosphate rock from the Vernal Mine north of Vernal, UT. An expanded mine at Vernal, a pipeline, and a new chemical complex at Rock Springs, WY, were scheduled to start operating in 1986. The phosphate rock will be reground to pass through a 150-mesh screen and pumped as a slurry through a buried 152-kilometer pipeline to Rock Springs at an initial rate of 1.1 million tons per year.

J. R. Simplot Co. operated the Gay Mine on the Fort Hall Indian Reservation. With the addition of new reserves obtained from the Shoshone and Bannock Indian Tribes, the mine was expected to produce for 17 years at a rate of 1.7 million tons per year. FMC Corp. received 80% of the ore, a 24% to 25% phosphorus pentoxide ($P_2O_5$) shale for consumption in its 0.9-million-kilogram-per-year $P_4$ plant near Pocatello, ID. Simplot used the remaining 20% of the mine production in its phosphoric acid plant near Pocatello.

Simplot replaced the Woodall Peak Mine near Conda, ID, with the Smoky Canyon Mine near Afton, WY. The ore was beneficiated at the mine, pumped to the calcining kilns at Conda, and shipped by rail to the fertilizer plant at Pocatello. Operating at 2 million tons per year, the Smoky Canyon Mine was expected to produce for 25 years.

### Table 2.—Production of phosphate rock in the United States, by region[1]

(Thousand metric tons and thousand dollars)

| Region | Mine production | | Marketable production | | | | | | | Ending stocks |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Used directly | | Beneficiated | | Total[2] | | | |
| | Rock | $P_2O_5$ content | Rock | $P_2O_5$ content | Rock | $P_2O_5$ content | Rock | $P_2O_5$ content | Value[3] | |
| 1984 | 163,012 | 21,017 | 8,104 | 2,343 | 41,094 | 12,546 | 49,197 | 14,889 | 1,182,244 | 11,897 |
| 1985: | | | | | | | | | | |
| January-June: | | | | | | | | | | |
| Florida and North Carolina | 86,305 | 10,746 | 3,313 | 1,000 | 20,377 | 6,834 | 23,690 | 7,335 | 545,581 | 13,115 |
| Tennessee | 1,107 | 223 | 15 | 4 | 635 | 165 | 650 | 169 | 14,567 | 175 |
| Western States[4] | 3,241 | 841 | 881 | 237 | 1,620 | 501 | 2,501 | 738 | 68,928 | 906 |
| Total[2] | 90,652 | 11,810 | 4,209 | 1,242 | 22,632 | 7,000 | 26,841 | 8,242 | [5]631,082 | 14,196 |
| July-December: | | | | | | | | | | |
| Florida and North Carolina | 80,165 | 9,882 | 2,798 | 853 | 18,708 | 5,813 | 21,506 | 6,666 | 497,434 | 14,691 |
| Tennessee | 1,223 | 239 | 13 | 3 | 570 | 147 | 584 | 151 | 13,058 | 151 |
| Western States[4] | 3,018 | 894 | 787 | 229 | 1,118 | 346 | 1,905 | 576 | 61,265 | 692 |
| Total[2] | 84,405 | 11,015 | 3,598 | 1,086 | 20,396 | 6,307 | 23,994 | 7,393 | [5]572,017 | 15,534 |
| Grand total[2] | 175,058 | 22,825 | 7,807 | 2,327 | 43,028 | 13,307 | 50,835 | 15,634 | [5]1,203,265 | XX |

XX Not applicable.

[1] Data for the same items appearing in this and other tables may not reconcile because of computer rounding.

[2] Data may not add to totals shown because of independent rounding.

[3] Computer calculated value based on the weighted sold or used value.

[4] Includes Idaho, Montana, and Utah.

[5] The total value is based on a weighted value. The total value does not equal the sum of the regional or 1/2-year totals because weighted regional or overall 1/2-year unit values were used in the calculations. The regional and 1/2-year values are approximate.

## CONSUMPTION AND USES

The U.S. primary demand for phosphate rock declined about 13% from its level in 1984 as the U.S. farm economy remained depressed. Phosphatic fertilizers sold well at unprofitable prices in the export market, which was the principal reason for sustaining demand in 1985.

With the exception of some low-grade phosphate pebble exported for electric-furnace consumption in Canada, phosphate rock from Florida and North Carolina was either consumed domestically or exported for fertilizer manufacture. Consumption of phosphate rock from Florida and North Carolina was about 12% less than the quantity consumed in 1984.

All of the phosphate rock mined in Tennessee was consumed in electric furnaces in Mount Pleasant and Columbia. Consumption was less than that of 1984. High-purity $P_4$ was used to produce technical- and food-grade phosphoric acid and other phosphate chemicals for multiple uses. The demand for sodium tripolyphosphate, the detergent builder, declined as the quantity permitted in the formulation of washing compounds was reduced by more States and municipalities.

In the Western States, a small percentage of the phosphate rock production was exported to fertilizer plants in western Canada. The domestic consumption pattern of phosphate rock from the Western States was about equally divided between fertilizer manufacturing and electric-furnace smelting. Overall demand was about 20% less than that of 1984 as consumption declined in the agricultural and industrial sectors.

### Table 3.—U.S. phosphate rock sold or used grade distribution pattern

| Grade (percent BPL[1] content) | Distribution (percent) | | | | |
|---|---|---|---|---|---|
| | 1981 | 1982 | 1983 | 1984 | 1985 |
| Less than 60 | 5.6 | 4.9 | 8.0 | 12.1 | 4.7 |
| 60 to less than 66 | 15.7 | 15.6 | 14.6 | 8.1 | 10.8 |
| 66 to less than 70 | 60.1 | 63.8 | 60.6 | 63.0 | 67.3 |
| 70 to less than 72 | 9.6 | 5.8 | 8.3 | 10.1 | 10.0 |
| 72 to less than 74 | 6.0 | 6.1 | 5.5 | 2.0 | 4.2 |
| 74 or more | 3.0 | 3.8 | 3.0 | 4.7 | 3.0 |

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% $P_2O_5$.

### Table 4.—Florida and North Carolina phosphate rock sold or used grade distribution pattern

| Grade (percent BPL[1] content) | Distribution (percent) | | | | |
|---|---|---|---|---|---|
| | 1981 | 1982[2] | 1983 | 1984 | 1985 |
| Less than 60 | 0.2 | 0.6 | 3.3 | 7.8 | 0.6 |
| 60 to less than 66 | 14.4 | 12.2 | 13.0 | 7.0 | 10.2 |
| 66 to less than 70 | 67.0 | 68.5 | 64.2 | 67.5 | 70.8 |
| 70 to less than 72 | 7.7 | 6.9 | 9.6 | 9.9 | 10.2 |
| 72 to less than 74 | 7.1 | 7.2 | 6.4 | 2.4 | 4.8 |
| 74 or more | 3.6 | 4.5 | 3.5 | 5.4 | 3.4 |

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% $P_2O_5$.
[2] Data do not add to 100% because of independent rounding.

### Table 5.—Tennessee phosphate rock sold or used grade distribution pattern

| Grade (percent BPL[1] content) | Distribution (percent) | | | | |
|---|---|---|---|---|---|
| | 1981 | 1982 | 1983 | 1984 | 1985 |
| Less than 60 | 50.6 | 38.0 | 89.4 | 100.0 | 100.0 |
| 60 to less than 66 | 49.4 | 62.0 | 10.6 | -- | -- |

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% $P_2O_5$.

### Table 6.—Western States phosphate rock sold or used grade distribution pattern

| Grade (percent BPL[1] content) | Distribution (percent) | | | | |
|---|---|---|---|---|---|
| | 1981 | 1982 | 1983 | 1984 | 1985[2] |
| Less than 60 | 31.4 | 27.2 | 25.2 | 27.0 | 15.7 |
| 60 to less than 66 | 16.0 | 29.4 | 27.5 | 19.1 | 19.6 |
| 66 to less than 70 | 28.5 | 43.4 | 47.3 | 39.6 | 54.2 |
| 70 to less than 72 | 24.1 | -- | -- | 14.3 | 10.4 |

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% $P_2O_5$.
[2] Data do not add to 100% because of independent rounding.

### Table 7.—Phosphate rock sold or used by producers in the United States, by grade and region[1]

(Thousand metric tons and thousand dollars)

| Grade (percent BPL[2] content) | Florida and North Carolina |  |  | Tennessee |  |  |
|---|---|---|---|---|---|---|
|  | Rock | $P_2O_5$ content | Value[3] | Rock | $P_2O_5$ content | Value[3] |
| January-June 1984 | 23,022 | 7,096 | 541,349 | 725 | 183 | 18,672 |
| July-December 1984 | 23,388 | 7,212 | 548,215 | 615 | 156 | 13,924 |
| January-June 1985: |  |  |  |  |  |  |
| Below 60 | -- | -- | -- | 669 | 173 | 14,992 |
| 60 to less than 66 | 2,019 | 574 | 37,654 | -- | -- | -- |
| 66 to less than 70 | 15,709 | 4,858 | 354,866 | -- | -- | -- |
| 70 to less than 72 | 1,799 | 586 | 45,155 | -- | -- | -- |
| 72 to less than 74 | 700 | 234 | 16,926 | -- | -- | -- |
| 74 or more | 763 | 261 | 28,902 | -- | -- | -- |
| Total | 20,990 | 6,508 | 483,400 | 669 | 173 | 14,992 |
| July-December 1985: |  |  |  |  |  |  |
| Below 60 | 236 | 64 | 5,074 | 607 | 157 | 13,566 |
| 60 to less than 66 | 2,158 | 617 | 41,067 | -- | -- | -- |
| 66 to less than 70 | 13,226 | 4,105 | 301,420 | -- | -- | -- |
| 70 to less than 72 | 2,374 | 772 | 58,747 | -- | -- | -- |
| 72 to less than 74 | 1,265 | 426 | 34,497 | -- | -- | -- |
| 74 or more | 609 | 210 | 23,721 | -- | -- | -- |
| Total | 19,868 | 6,194 | 459,547 | 607 | 157 | 13,566 |

| Grade (percent BPL[2] content) | Western States[4] |  |  | Total |  |  |
|---|---|---|---|---|---|---|
|  | Rock | $P_2O_5$ content | Value[3] | Rock | $P_2O_5$ content | Value[3] [5] |
| January-June 1984 | 2,481 | 711 | 73,045 | 26,178 | 7,990 | 633,066 |
| July-December 1984 | 3,096 | 887 | 83,097 | 27,098 | 8,254 | 645,203 |
| January-June 1985: |  |  |  |  |  |  |
| Below 60 | 645 | 159 | 8,649 | 1,314 | 332 | 23,639 |
| 60 to less than 66 | 491 | 136 | 8,725 | 2,510 | 710 | 46,360 |
| 66 to less than 70 | 1,295 | 401 | 44,626 | 17,004 | 5,254 | 399,424 |
| 70 to less than 72 | 261 | 84 | 12,196 | 2,060 | 670 | 57,350 |
| 72 to less than 74 | -- | -- | -- | 700 | 234 | 16,926 |
| 74 or more | -- | -- | -- | 763 | 261 | 28,902 |
| Total | 2,692 | 780 | 74,191 | 24,851 | 7,461 | 572,422 |
| July-December 1985: |  |  |  |  |  |  |
| Below 60 | 61 | 16 | 1,338 | 904 | 237 | 19,978 |
| 60 to less than 66 | 394 | 112 | 9,026 | 2,552 | 729 | 50,096 |
| 66 to less than 70 | 1,147 | 355 | 36,004 | 14,373 | 4,460 | 337,478 |
| 70 to less than 72 | 209 | 67 | 11,869 | 2,583 | 839 | 65,608 |
| 72 to less than 74 | -- | -- | -- | 1,265 | 426 | 34,497 |
| 74 or more | -- | -- | -- | 609 | 210 | 23,721 |
| Total | 1,811 | 550 | 58,242 | 22,286 | 6,901 | 531,275 |

[1] Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[2] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% $P_2O_5$.
[3] F.o.b. mine.
[4] Includes Idaho, Montana, and Utah.
[5] The total value is based on a weighted value. The total value does not equal the sum of the regional totals because weighted regional unit values were used in the calculations. The regional values are approximate.

## Table 8.—Phosphate rock sold or used by producers in the United States, by use[1]

(Thousand metric tons)

| Use | 1984 total | | 1985 | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | January-June | | July-December | | Total[2] | |
| | Rock | $P_2O_5$ content | Rock | $P_2O_5$ content | Rock | $P_2O_5$ content | Rock | $P_2O_5$ content |
| Domestic:[3] | | | | | | | | |
| Wet-process phosphoric acid | 36,651 | 11,207 | 16,650 | 5,121 | 15,394 | 4,752 | 32,044 | 9,873 |
| Normal superphosphate | 103 | 34 | 47 | 16 | 25 | 8 | 72 | 24 |
| Triple superphosphate | 1,062 | 336 | 806 | 255 | 635 | 209 | 1,441 | 463 |
| Defluorinated rock | 68 | 24 | 26 | 9 | 29 | 10 | 55 | 19 |
| Direct applications | 95 | 33 | 51 | 17 | 44 | 15 | 94 | 32 |
| Elemental phosphorus | 3,722 | 953 | 1,689 | 436 | 910 | 241 | 2,599 | 677 |
| Ferrophosphorus | 48 | 12 | 22 | 6 | 22 | 6 | 45 | 12 |
| Total[2] | 41,748 | 12,598 | 19,291 | 5,859 | 17,059 | 5,241 | 36,350 | 11,100 |
| Exports[4] | 11,528 | 3,646 | 5,057 | 1,602 | 5,226 | 1,660 | 10,284 | 3,263 |
| Grand total[2] | 53,277 | 16,244 | 24,348 | 7,461 | 22,285 | 6,901 | 46,634 | 14,363 |

[1] Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes rock converted to products and exported.
[4] Exports reported to the Bureau of Mines by companies.

## Table 9.—Phosphate rock sold or used by producers in the United States, by use and region[1]

(Thousand metric tons)

| Use | Florida and North Carolina | | Tennessee | | Western States[2] | | Total[3] | |
|---|---|---|---|---|---|---|---|---|
| | Rock | $P_2O_5$ content | Rock | $P_2O_5$ content | Rock | $P_2O_5$ content | Rock | $P_2O_5$ content |
| 1984 | 46,411 | 14,309 | 1,340 | 338 | 5,526 | 1,597 | 53,277 | 16,244 |
| 1985: | | | | | | | | |
| January-June: | | | | | | | | |
| Domestic:[4] | | | | | | | | |
| Agricultural | 16,436 | 5,064 | -- | -- | 1,143 | 353 | 17,579 | 5,418 |
| Industrial | 7 | 2 | 669 | 173 | 1,036 | 266 | 1,712 | 442 |
| Total | 16,443 | 5,066 | 669 | 173 | 2,179 | 619 | 19,291 | 5,860 |
| Exports[5] | 4,547 | 1,442 | -- | -- | 511 | 161 | 5,057 | 1,602 |
| Total | 20,990 | 6,508 | 669 | 173 | 2,690 | 780 | 24,348 | 7,462 |
| July-December: | | | | | | | | |
| Domestic:[4] | | | | | | | | |
| Agricultural | 15,106 | 4,678 | -- | -- | 1,021 | 316 | 16,127 | 4,994 |
| Industrial | 6 | 2 | 607 | 157 | 319 | 88 | 932 | 247 |
| Total | 15,112 | 4,680 | 607 | 157 | 1,340 | 404 | 17,059 | 5,241 |
| Exports[5] | 4,756 | 1,514 | -- | -- | 470 | 146 | 5,229 | 1,660 |
| Total[3] | 19,868 | 6,194 | 607 | 157 | 1,810 | 550 | 22,285 | 6,901 |
| Grand total[3] | 40,857 | 12,701 | 1,276 | 330 | 4,501 | 1,331 | 46,634 | 14,364 |

[1] Data for the same items appearing in this and other tables may not reconcile because of computer rounding.
[2] Includes Idaho, Montana, and Utah.
[3] Data may not add to totals shown because of independent rounding.
[4] Includes rock converted to products and exported.
[5] Exports reported to the Bureau of Mines by companies.

### Table 10.—Florida and North Carolina phosphate rock sold or used by producers[1]

| Year | Rock (thousand metric tons) | $P_2O_5$ content (thousand metric tons) | Value | |
|---|---|---|---|---|
| | | | Total (thousands) | Average per ton |
| 1981 ---- | 38,458 | 11,935 | $1,064,459 | $27.68 |
| 1982 ---- | 32,806 | 10,192 | 850,794 | 25.93 |
| 1983 ---- | 40,223 | 12,456 | 944,509 | 23.48 |
| 1984 ---- | 46,411 | 14,309 | 1,089,647 | 23.48 |
| 1985 ---- | 40,856 | 12,703 | 942,956 | 23.08 |

[1] Data for the same items appearing in this or other tables may not reconcile because of computer rounding.

### Table 11.—Tennessee phosphate rock sold or used by producers[1]

| Year | Rock (thousand metric tons) | $P_2O_5$ content (thousand metric tons) | Value | |
|---|---|---|---|---|
| | | | Total (thousands) | Average per ton |
| 1981 ---- | 1,379 | 357 | $17,401 | $12.62 |
| 1982 ---- | 960 | 248 | 12,972 | 13.51 |
| 1983 ---- | 1,187 | 307 | 28,935 | 24.38 |
| 1984 ---- | 1,340 | 338 | 32,590 | 24.32 |
| 1985 ---- | 1,276 | 330 | 28,557 | 22.38 |

[1] Data for the same items appearing in this or other tables may not reconcile because of computer rounding.

### Table 12.—Western States phosphate rock sold or used by producers[1]

| Year | Rock (thousand metric tons) | $P_2O_5$ content (thousand metric tons) | Value | |
|---|---|---|---|---|
| | | | Total (thousands) | Average per ton |
| 1981 ---- | 5,672 | 1,644 | $130,194 | $22.95 |
| 1982 ---- | 4,807 | 1,375 | 119,699 | 24.90 |
| 1983 ---- | 5,428 | 1,578 | 149,520 | 27.55 |
| 1984 ---- | 5,526 | 1,597 | 156,119 | 28.25 |
| 1985 ---- | 4,500 | 1,330 | [2]132,345 | 29.41 |

[1] Data for the same items appearing in this and other tables may not reconcile because of computer rounding.

[2] The total value is based on a weighted value.

## STOCKS

Inventories of marketable phosphate rock were reported to the Bureau of Mines by producing companies on a monthly and semiannual basis. The data from the monthly surveys permitted the Bureau to publish the increase or decrease of stocks throughout the year in the monthly "Phosphate Rock Mineral Industry Survey." The semiannual surveys permitted respondents to adjust or correct reported stock levels, and these changes were reported in the "Annual Advance Summary Mineral Industry Survey," the "Crop Year Mineral Industry Survey," and the "Minerals Yearbook."

The significant decrease in 1984 stock levels from those of 1981, 1982, and 1983 reflected improvement in phosphate rock demand during 1984. During 1985, inventories of phosphate rock gradually increased as demand declined throughout the year.

### Table 13.—Marketable phosphate rock yearend stocks

(Million metric tons)

| Year | Quantity |
|---|---|
| 1976 ------------------------ | 15.2 |
| 1977 ------------------------ | 13.7 |
| 1978 ------------------------ | 15.7 |
| 1979 ------------------------ | 14.5 |
| 1980 ------------------------ | 13.7 |
| 1981 ------------------------ | 19.6 |
| 1982 ------------------------ | 18.3 |
| 1983 ------------------------ | 14.5 |
| 1984 ------------------------ | 11.9 |
| 1985 ------------------------ | 15.5 |

## PRICES

Phosphate rock was sold under contracts negotiated between buyers and sellers. Although list prices were occasionally published by producing organizations, actual contract prices negotiated between buyer and seller were not published.

Phosphate rock export prices from Tampa and Jacksonville, FL, included a freight, loading, and weighing cost of $6.10 and $7.90 per ton, respectively. The severance tax, included in the export price, was $2.52 per ton.

The weighted average prices or values, f.o.b. mine, for each grade of phosphate rock and for each producing State were calculated by the Bureau of Mines from the semiannual survey of producing mines.

### Table 14.—Phosphate rock estimated export prices[1] per metric ton, unground, f.o.b. vessel Tampa Range or Jacksonville, FL, by grade

| Grade (percent BPL[2] content) | 1982[3] | 1983[4] | 1984[5] | 1985[6] |
|---|---|---|---|---|
| 68 | $23.00 | $27.00 | $26.50 | $26.00 |
| 70 | 23.50 | 28.00 | 27.50 | 28.00 |
| 72 | 27.00 | 30.00 | 30.50 | 30.50 |
| 75 | 34.00 | 35.00 | 35.00 | 34.00 |

[1] Prices include severance taxes, rail freight costs from mine to port, and port loading and weighing charges.
[2] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% $P_2O_5$.
[3] Estimated selling price including $2.08 severance tax.
[4] Estimated selling price including $2.25 severance tax.
[5] Estimated selling price including $2.39 severance tax.
[6] Estimated selling price including $2.52 severance tax.

### Table 15.—Moroccan phosphate rock export prices, U.S. dollars per metric ton, f.a.s. Safi or Casablanca,[e] by grade

| Grade (percent BPL[1] content) | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|
| Khouribga: | | | | |
| 70 to 71 | 42.00 | 35.00 | 36.00 | 36.00 |
| 76 to 77 | 50.00 | 45.00 | 47.00 | 47.00 |
| Youssoufia: | | | | |
| 68 to 69 | 33.00 | 29.00 | 30.00 | 30.00 |
| 74 to 75 | 47.00 | 41.00 | 43.00 | 43.00 |

[e] Estimated.
[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% $P_2O_5$.

### Table 16.—Price or value of Florida and North Carolina phosphate rock, by grade

(Dollars per metric ton, f.o.b. mine)

| Grade (percent BPL[1] content) | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Domestic | Export | Average | Domestic | Export | Average |
| Less than 60 | 25.14 | 25.64 | 25.28 | 21.50 | -- | 21.50 |
| 60 to less than 66 | 20.90 | 20.10 | 20.75 | 18.59 | 20.69 | 18.84 |
| 66 to less than 70 | 22.19 | 24.51 | 22.45 | 22.75 | 22.28 | 22.63 |
| 70 to less than 72 | 25.34 | 25.75 | 25.65 | 21.98 | 24.63 | 23.70 |
| 72 to less than 74 | 24.49 | 32.10 | 28.08 | 22.59 | 30.86 | 26.17 |
| 74 or more | 29.31 | 33.01 | 31.40 | 34.44 | 40.77 | 38.35 |
| Average | 22.67 | 26.28 | 23.48 | 22.41 | 25.35 | 23.08 |

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% $P_2O_5$.

### Table 17.—Price or value of Western States phosphate rock, by grade

(Dollars per metric ton, f.o.b. mine)

| Grade (percent BPL[1] content) | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Domestic | Export | Average | Domestic | Export | Average |
| Less than 60 | 15.22 | -- | 15.22 | 14.14 | -- | 14.14 |
| 60 to less than 66 | 11.15 | 41.51 | 16.33 | 11.81 | 42.95 | 20.06 |
| 66 to less than 70 | 32.14 | 44.81 | 35.80 | 31.90 | 41.79 | 33.02 |
| 70 to less than 72 | 45.78 | 51.45 | 47.87 | -- | 51.20 | 51.20 |
| Average | 23.81 | 46.03 | 28.25 | 24.63 | 46.58 | 29.41 |

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% $P_2O_5$.

### Table 18.—Price or value of Tennessee phosphate rock, by grade

(Dollars per metric ton, f.o.b. mine)

| Grade (percent BPL[1] content) | 1984 | 1985 |
|---|---|---|
| Less than 60 | 24.32 | 22.38 |

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% $P_2O_5$.

### Table 19.—Price or value of U.S. phosphate rock, by grade

(Dollars per metric ton, f.o.b. mine)

| Grade (percent BPL[1] content) | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Domestic | Export | Average | Domestic | Export | Average |
| Less than 60 | 22.25 | 25.64 | 22.75 | 19.66 | -- | 19.66 |
| 60 to less than 66 | 18.47 | 24.94 | 19.67 | 17.57 | 27.76 | 19.06 |
| 66 to less than 70 | 22.72 | 27.62 | 23.32 | 23.49 | 23.44 | 23.48 |
| 70 to less than 72 | 31.55 | 27.77 | 28.93 | 21.98 | 28.56 | 26.48 |
| 72 to less than 74 | 24.49 | 32.10 | 28.08 | 22.59 | 30.86 | 26.17 |
| 74 or more | 29.31 | 33.01 | 31.40 | 34.44 | 40.77 | 38.35 |
| Average | 22.84 | 28.17 | 23.99 | 22.62 | 27.38 | 23.67 |

[1] 1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% $P_2O_5$.

## FOREIGN TRADE

Phosphate rock export tonnage declined 11% from that of 1984, breaking a trend of increasing phosphate rock exports that began in 1981. The decline in exports was attributed to increased competition from other phosphate rock exporting countries and a reduction in world demand. Erosion of trade in phosphate rock was further exacerbated by increased trade in high analysis phosphate fertilizers. Trade in ammonium phosphates, triple superphosphate, and phosphoric acid increased as more countries with phosphate rock reserves produced phosphoric acid and phosphate fertilizers for export markets.

In Florida, increases in rail freight rates from mine to port, port charges, and the severance tax reduced the competitive position of phosphate rock exports.

Trade in phosphate fertilizers was characterized by oversupply and weakening prices throughout the year. Nameplate capacity of phosphate fertilizer plants exceeded the demand for these commodities. The plant capacity utilization rate was reduced to 65% or 70%.

The quantity of phosphate rock imported into the United States in 1985, as reported by the Bureau of the Census, is shown in the following tabulation:

| Country of origin | Metric tons |
|---|---|
| Belgium | 36 |
| Dominican Republic | 60 |
| Israel | 47 |
| Mexico | 208 |
| Netherlands | 2,791 |
| Netherlands Antilles | 4,158 |
| Togo | 26,200 |
| United Kingdom | 391 |
| Total | 33,891 |

NOTE: Reported imports from Canada are excluded.

## Table 20.—U.S. exports of phosphate rock, by country

(Thousand metric tons and thousand dollars)

(Schedule B No. 480.4500)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value[1] | Quantity | Value[1] |
| Australia | 212 | 6,199 | 98 | NA |
| Austria | 20 | 6 | -- | |
| Belgium-Luxembourg | 549 | 17,454 | 383 | |
| Brazil | 12 | 709 | 27 | |
| Canada | 2,998 | 106,479 | 2,643 | |
| Finland | 149 | 4,967 | 162 | |
| France | 702 | 23,856 | 668 | |
| Germany, Federal Republic of | 541 | 16,770 | 665 | |
| India | 248 | 9,954 | 480 | |
| Italy | 85 | 2,640 | 97 | |
| Japan | 1,274 | 50,843 | 803 | |
| Korea, Republic of | 1,501 | 46,750 | 1,540 | |
| Mexico | 429 | 12,861 | 258 | |
| Netherlands | 640 | 18,957 | 555 | |
| New Zealand | 51 | 1,578 | 116 | |
| Philippines | 25 | 974 | 30 | |
| Poland | [e]700 | [e]20,894 | 754 | |
| Romania | 433 | 17,435 | 223 | |
| Sweden | 187 | 6,797 | 83 | |
| Taiwan | 23 | 854 | -- | |
| United Kingdom | 26 | 854 | -- | |
| Other | [r]511 | [r]24,201 | 699 | |
| Total | 11,316 | 392,032 | [2]10,284 | [2]281,515 |

[e] Estimated. [r] Revised. NA Not available.

[1] All values f.a.s. (free alongside ship).

[2] Total quantity and value reported to the Bureau of Mines, f.o.b. mine.

Source: Bureau of the Census.

## Table 21.—U.S. exports of superphosphates, more than 40% $P_2O_5$, by country

(Thousand metric tons and thousand dollars)

(Schedule B No. 480.7050)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value[1] | Quantity | Value[1] |
| Argentina | 9 | 1,107 | 3 | NA |
| Belgium-Luxembourg | 78 | 9,208 | 111 | |
| Brazil | 44 | 6,031 | 158 | |
| Bulgaria | 92 | 11,781 | 20 | |
| Burma | 15 | 2,840 | -- | |
| Canada | 204 | 30,867 | 289 | |
| Chile | 182 | 15,660 | 158 | |
| Colombia | 15 | 2,720 | 17 | |
| Costa Rica | 8 | 1,035 | 9 | |
| Dominican Republic | 8 | 1,490 | 31 | |
| France | 9 | 1,063 | 62 | |
| Germany, Federal Republic of | 80 | 9,772 | 58 | |
| Hungary | 15 | 1,739 | -- | |
| Ireland | 38 | 4,887 | 27 | |
| Italy | 7 | 924 | 10 | |
| Japan | 30 | 4,286 | 34 | |

See footnotes at end of table.

## Table 21.—U.S. exports of superphosphates, more than 40% $P_2O_5$, by country—Continued

(Thousand metric tons and thousand dollars)

(Schedule B No. 480.7050)

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value[1] | Quantity | Value[1] |
| Peru | 14 | 1,987 | 16 | NA |
| Uruguay | 6 | 829 | 9 |  |
| Venezuela | 8 | 1,548 | 1 |  |
| Other | 228 | 39,322 | 403 |  |
| Total | 1,090 | 149,096 | 1,416 | 176,417 |

NA Not available.
[1] All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

## Table 22.—U.S. exports of superphosphates, less than 40% $P_2O_5$, by country

(Schedule B No. 480.7080)

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (metric tons) | Value[1] (thousands) | Quantity (metric tons) | Value[1] (thousands) |
| Canada | 1,097 | $24 | 3,651 | $79 |
| Other | 660 | 30 | 457 | 19 |
| Total | 1,757 | 54 | 4,108 | 98 |

[1] All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

## Table 23.—U.S. exports of diammonium phosphates, by country

(Thousand metric tons and thousand dollars)

(Schedule B No. 480.8005)

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value[1] | Quantity | Value[1] |
| Argentina | 84 | 15,901 | 59 | NA |
| Australia | 206 | 41,339 | 230 |  |
| Belgium-Luxembourg | 748 | 139,672 | 482 |  |
| Brazil | 91 | 17,660 | 35 |  |
| Canada | 115 | 22,753 | 193 |  |
| Chile | 51 | 10,257 | 65 |  |
| China | 1,229 | 230,928 | 789 |  |
| Colombia | 61 | 11,920 | 97 |  |
| Costa Rica | 19 | 3,838 | 25 |  |
| Dominican Republic | 31 | 5,849 | 38 |  |
| Ecuador | 39 | 7,788 | 33 |  |
| France | 19 | 3,769 | 50 |  |
| Germany, Federal Republic of | 27 | 5,028 | 81 |  |
| Guatemala | 13 | 2,962 | 18 |  |
| India | 1,189 | 227,337 | 1,853 |  |
| Ireland | 34 | 5,775 | 51 |  |
| Italy | 128 | 24,357 | 174 |  |
| Japan | 488 | 92,197 | 349 |  |
| Mexico | 267 | 52,049 | 186 |  |
| Netherlands | 19 | 3,394 | 70 |  |
| New Zealand | 45 | 8,978 | 36 |  |
| Nicaragua | 19 | 2,812 | -- |  |
| Pakistan | 247 | 48,680 | 326 |  |
| Thailand | 68 | 12,335 | 34 |  |
| Turkey | 60 | 11,844 | 230 |  |
| Uruguay | -- | -- | 49 |  |
| Yugoslavia | 79 | 15,268 | 120 |  |
| Other | 970 | 175,889 | 458 |  |
| Total | 6,346 | 1,200,579 | 6,131 | 1,048,322 |

NA Not available.
[1] All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

### Table 24.—U.S. exports of phosphoric acid, less than 65% $P_2O_5$, by country

(Thousand metric tons and thousand dollars)

(Schedule B No. 480.7015)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value[1] | Quantity | Value[1] |
| Canada | 3 | 520 | 2 | NA |
| Colombia | 9 | 2,061 | 6 | |
| Germany, Federal Republic of | 54 | 13,397 | 24 | |
| India | 212 | 45,001 | 378 | |
| Indonesia | 95 | 20,465 | 42 | |
| Mexico | 21 | 4,051 | -- | |
| Turkey | 140 | 25,612 | 63 | |
| Venezuela | 100 | 23,322 | 146 | |
| Other | 233 | 46,626 | 55 | |
| Total | 867 | 181,055 | 716 | 141,162 |

NA Not available.
[1] All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

### Table 25.—U.S. exports of elemental phosphorus, by country

(Schedule B No. 415.3500)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (metric tons) | Value[1] (thousands) | Quantity (metric tons) | Value[1] (thousands) |
| Brazil | 3,270 | $5,068 | 1,504 | NA |
| Canada | 1,518 | 1,888 | 6,093 | |
| China | 2,300 | 2,816 | -- | |
| Japan | 5,776 | 9,647 | 7,706 | |
| Korea, Republic of | 496 | 752 | 718 | |
| Mexico | 19 | 78 | 17 | |
| Taiwan | 793 | 986 | 835 | |
| Other | 680 | 1,140 | 258 | |
| Total | 14,852 | 22,875 | 17,131 | $27,024 |

NA Not available.
[1] All values f.a.s. (free alongside ship).

Source: Bureau of the Census.

### Table 26.—U.S. imports for consumption of phosphate rock and phosphatic materials

(Thousand metric tons and thousand dollars)

| Fertilizer | TSUS No. | 1984 | | 1985 | |
|---|---|---|---|---|---|
| | | Quantity | Value[1] | Quantity | Value[1] |
| Phosphates, crude and apatite[2] | 480.4500 | 9 | 274 | 34 | 1,598 |
| Phosphatic fertilizers and fertilizer materials | 480.7070, 480.8095 | 119 | 7,536 | 30 | 5,929 |
| Dicalcium phosphate | 418.2800 | [r]1 | 378 | 1 | 841 |
| Phosphorus | 415.3500 | [r]4 | 6,482 | 2 | 3,580 |
| Phosphoric acid, technical- and food-grade | 416.3000 | [r]10 | 4,060 | -- | -- |
| Phosphoric acid, fertilizer-grade | 480.7010 | 1 | 380 | (3) | 68 |
| Normal superphosphate | 480.7030 | 1 | 141 | 1 | 120 |
| Triple superphosphate | 480.7050 | 9 | 1,029 | 2 | 304 |

[r] Revised.
[1] Declared customs valuation.
[2] Excludes reported imports from Canada and Israel.
[3] Less than 1/2 unit.

Source: Bureau of the Census.

## WORLD REVIEW

During the past decade, world phosphoric acid capacity had increased from 19 million tons $P_2O_5$ equivalent to 35 million tons $P_2O_5$ as countries with phosphate rock mines determined that it was economically advantageous to upgrade phosphate rock to phosphoric acid or ammonium phosphates. New, efficient, low-cost wet-process phosphoric acid plants were constructed in countries with indigenous phosphate rock deposits to increase exports of these higher value commodities. Historically, the United States had been the only country exporting phosphoric acid and solid fertilizers produced from domestic raw materials. One of the effects of new downstream plants constructed for the export market was to limit phosphate rock trade. The rate of increase of phosphate rock trade has been steadily declining.

The International Fertilizer Industry Association reported that in 1984, the latest full year of data available, Morocco was the largest exporter of phosphoric acid, followed by the United States, Tunisia, the Republic of South Africa, and Jordan. The total phosphoric acid traded internationally in 1984 was 2.5 million tons $P_2O_5$, which was equivalent to about 8.3 million tons of 70% bone phosphate of lime (BPL) phosphate rock. For comparison purposes, international trade in phosphate rock in 1984 was about 48 million tons.

**Brazil.**—With the exception of a local supply for the Sotave Amazonia Quimica project on Caratateua Island near Belém, Brazil has been self-sufficient in phosphate rock. Phosphate rock for annual production of 300,000 tons of complex fertilizers and 300,000 tons of single and triple superphosphate at the project was to be imported from the United States. The plants were scheduled to start in 1986.

**China.**—The principal phosphate rock producing Provinces in China were Guizhou, Hubei, Hunan, Jiangsu, Sichuan, and Yunnan. In a report[3] given at the 10th enlarged council meeting of the International Fertilizer Industry Association, phosphate rock production was reported to be 11.7 million tons in 1984 and increasing at an average rate of 7.8% per year. Phosphate rock reserves were reported to be 11.8 billion tons. Over 90% of the phosphatic fertilizer produced in China was single superphosphate and fused magnesium phosphate.

**Christmas Island.**—Phosphate Mining Co. of Christmas Island shipped phosphate rock to China, Japan, the Republic of Korea, Malaysia, and Taiwan. A Grade phosphate rock, 35% $P_2O_5$, was exported. It was estimated by the operators that only a few million tons of A Grade material remained in the reserve. The remaining reserve, classified as B Grade, was about 50 million tons.

**Egypt.**—A contract was awarded to construct a washing and flotation plant at the West Sabaeya Mine in Upper Egypt. The plant was designed to process 3,500 tons per day of ore. Plans were to pump the concentrates 4 kilometers to a site on the Nile for shipment by barge to the Zaabal Fertilizer & Chemical Co. plant in Lower Egypt.[3]

**Finland.**—Production from the Siilinjarvi Mine increased from 200,000 tons in 1980 to 500,000 tons in 1985. The flotation concentrates averaged 35.5% $P_2O_5$ and 1.45% magnesium oxide (MgO). Byproduct recovery of calcite was accomplished by flotation of the apatite flotation tailings. About 100,000 tons of the calcite was sold as agricultural lime in the adjacent farming districts. Phosphogypsum recovered from the phosphoric acid plant was stockpiled. A 50,000-ton-per-year coating-pigment plant had been constructed in 1984 to use the stockpiled phosphogypsum.

**India.**—Of the three main Indian phosphate rock deposits, Mussoorie in Utter Pradesh and Jhamar Kotra and Jhabua in Rajasthan, only the Jhamar Kotra rock has been suitable for manufacturing phosphate fertilizers. Mussoorie and Jhabua phosphate rock has been ground for direct application. With limited domestic supplies of phosphate rock, India has relied on imported processed phosphates to meet increasing fertilizer demand.

**Israel.**—Negev Phosphates Ltd. operated the Nahal Zin and Oron Mines in the Negev Desert. To increase phosphate rock capacity, a secondary crushing station was installed at the Nahal Zin Mine and a coal-fired calcining kiln was installed at Oron. Reserves of the recently discovered high-grade Bikaal deposit between Arad and Beersheba were estimated to be 100 million tons. To increase phosphate rock production and meet Negev Phosphates' targets for 1990, plans were to expand the Nahal Zin Mine and mine the Bikaal deposit.[4]

**Jordan.**—Jordan Phosphate Mines Co. (JPMC) demonstrated that large areas of the country have phosphate resources. The three principal areas are Ruseifa, 15 kilometers north of Amman; El Abyad and El Hasa, 120 to 140 kilometers south of Amman; and Shidiya, 230 kilometers south of Amman. Most of JPMC's production, about 5 million tons per year, has been from El Hasa. Production from Ruseifa has been about 800,000 tons per year. The phosphate rock from both mining areas was beneficiated by wet screening, desliming, and drying. JPMC planned to produce 3 million tons per year from the Shidiya deposit, with reported reserves of 500 million tons. Plans were to expand the mine to 9 million tons per year by the end of the century.

**Mexico.**—Construction of a 3-million-ton-per-year $P_2O_5$ addition to the fertilizer complex at Lázaro Cárdenas was scheduled for completion in 1985. The expansion was designed for annual production of 396,000 tons of phosphoric acid, 215,000 tons of nitric acid, 215,000 tons of ammonium nitrate, and more than 1 million tons of compound fertilizers. At the San Juan de la Costa Mine on the Baja California Sur, a concentrate drying plant was installed to augment sun drying. With the drying facility, additional trucks, and front-end loaders, Roca Fosfórica Mexicana S.A. de C.V. (ROFOMEX) planned to be able to achieve the original design capacity of 700,000 tons per year by 1985. Additional phosphate rock mining was planned for ROFOMEX's San Hilario and Tembabiche deposits.

**Morocco.**—Production of phosphate rock continued from the Sidi Daoui and Meraa el Arech open pit mines in the Khouribga

District. Five active underground mines at Khouribga were programmed to be phased out as more open pit capacity was developed. At Youssoufia, surface mining ended. White rock was mined from Recette 4 and 5. Black rock from Recette 7 was calcined in a fluidized bed kiln at a rate of 600,000 tons per year. Three additional kilns were being erected, each with a design capacity of 1.2 million tons per year. A new 4-million-ton-per-year dry beneficiation plant began operating with concentrates from the Beni-Idir drying plant. Concentrates from the Ben Guerir Mine were shipped to Safi, washed with seawater to reduce the MgO content, and processed at Maroc Phosphore II into phosphoric acid for export. The initial exploration of the Meskala deposits ended. A drilling program was planned in cooperation with the U.S.S.R. to obtain more information on favorable areas. Production from the Bu Craa Mine in the Western Sahara was limited to about 1 million tons per year by inadequate crushing and screening capacity at the mine and insufficient freshwater at the Laayoun beneficiating plant. These bottlenecks were being corrected to increase capacity to 2 million tons per year. The port and chemical complex at Jorf Lasfar was expected to be completed in the first quarter of 1986. The complex was designed for annual production of 1.5 million tons $P_2O_5$ phosphoric acid, 600,000 tons per year triple superphosphate, and 396,000 tons per year monoammonium phosphate from Khouribga District phosphate rock.

**Pakistan.**—A new phosphate rock mine near Kakul, in the Northwest Frontier Province, about 75 kilometers north of Islamabad, was expected to produce about 1 million tons per year for consumption by National Fertilizer Corp.

**Senegal.**—Compagnie Sénégalaise des Phosphates de Taïba (CSPT) produced approximately 2 million tons of calcium phosphate concentrates, and Société Sénégalaise des Phosphates de Thies produced 600,000 tons of aluminum phosphates. CSPT had reserves of 20 million tons in the Keur Mor Fall deposit and 60 million tons in the nearby Tobene deposit. The Société d'Etudes des Industries Chimiques du Senegal constructed a 476,000-ton, merchant-grade phosphoric acid plant at Darow-Khoudoss near the Taïba Mine.

**South Africa, Republic of.**—Phosphate Development Corp. Ltd. was working on the reclamation of phosphate rock from tailings and on improving the efficiency of classification in the phosphate rock grinding circuits. Increased production of 86% BPL phosphate rock was anticipated with installation of more effective filters in early 1986. In the foskorite flotation plant, a new desliming system was installed. The advantages expected were reduced consumption of flotation reagents and decreased MgO content.[5]

**Togo.**—Feasibility studies were authorized by the Office Togolaise des Phosphates to develop a new phosphate rock mine at Dagbati. Demand for Togo's high-grade phosphate rock prompted reopening of the Hahotoe-K'pogame Mine's fifth beneficiation line, which had been closed since 1981. The high price of sulfur was in part responsible for increased exports of Togolese phosphate rock, because high-grade phosphate rock usually requires less sulfuric acid per ton of phosphòric acid produced.

**Tunisia.**—Société Tunisienne de Exploritation Phosphatieres Co. mined the Kalaa Djerda deposit in central Tunisia. In the Gafsa Basin, phosphate rock was mined by Compagnie des Phosphates de Gafsa (CPG). CPG was modernizing facilities at the Moulares, M'Dilla, and Sehib Mines to raise capacities and the quality of the phosphate rock. New mines and plants at Kef Eddour and Jellabia were planned for operation in 1986. Tunisia and Kuwait established the Société Sra Ourtane Co. to plan the production of 10 million tons per year of phosphate rock from the Sra Ourtane deposit by the year 2000.

**U.S.S.R.**—The U.S.S.R. announced the discovery of phosphate deposits in the Kyzyl Kum Desert. The deposits are within a 1,500-kilometer radius of Muruntau.[6] At the Black Sea port of Yuzhnyy, two mechanical ship unloaders, conveyor systems, storage sheds, stackers, and scraper reclaimers were being installed to handle 1.2 million tons per year of phosphate rock from Morocco. It was planned to double the capacity of the installation to accept increasing phosphate rock tonnage from Morocco. At the "Apatit" industrial complex of Khibiny on the Kola Peninsula, which produces about 80% of the U.S.S.R.'s phosphate rock, mining was conducted in three underground and two open pit sites. About 45 million tons of ore was mined from the open pits and 17 million tons from the underground mines. As the open pits are depleted, the U.S.S.R. intends to increase production from the underground mines.[7]

## Table 27.—Phosphate rock, basic slag, and guano: World production, by country[1]

(Thousand metric tons)

| Commodity and country[2] | Gross weight |  |  |  |  | $P_2O_5$ content |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | 1981 | 1982 | 1983 | 1984[p] | 1985[e] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
| Phosphate rock: |  |  |  |  |  |  |  |  |  |  |
| Algeria | 916 | 947 | 893 | 1,000 | [3]1,207 | 262 | 289 | 276 | 309 | 381 |
| Australia | 22 | 211 | 21 | 17 | 34 | 6 | 59 | 1 | 4 | 8 |
| Brazil | 3,238 | 2,732 | 3,208 | 3,855 | 4,214 | 979 | 1,141 | 1,119 | 1,345 | 1,475 |
| China[e] | 11,500 | 11,720 | 12,500 | [r]14,210 | 12,000 | 2,530 | 2,580 | 3,750 | [r]4,263 | 3,600 |
| Christmas Island (Indian Ocean) | 1,423 | 1,328 | 1,094 | 1,259 | [3]1,200 | 499 | 466 | 385 | 443 | 421 |
| Colombia | 17 | 20 | 17 | 28 | 23 | 4 | 4 | 4 | 7 | 6 |
| Egypt | 720 | 711 | 647 | 1,043 | 1,074 | 208 | 200 | 205 | 253 | 246 |
| Finland | 201 | 233 | 381 | 477 | [3]510 | 72 | 83 | 141 | 176 | [3]177 |
| India | [r]565 | [r]631 | 688 | 800 | 748 | [r]176 | [r]197 | 212 | 275 | 233 |
| Indonesia | 8 | 5 | 6 | 2 | 3 | 3 | 2 | 2 | 1 | 1 |
| Iraq | [e]50 | 363 | [e]1,199 | 1,000 | 1,000 | [e]16 | [e]113 | [e]261 | [r][e]218 | 218 |
| Israel | 1,919 | 2,148 | 2,969 | 3,312 | 4,076 | 624 | 698 | 892 | 995 | 1,210 |
| Jordan | 4,244 | 4,390 | 4,749 | 6,263 | [3]6,067 | 1,379 | 1,427 | 1,548 | 2,042 | 2,005 |
| Korea, North[e] | 500 | 500 | 500 | 500 | 500 | 150 | 150 | 160 | 160 | 160 |
| Mexico | 252 | 379 | 389 | 375 | 350 | 150 | 195 | 114 | 110 | 107 |
| Morocco[4] | 18,562 | 17,754 | 20,106 | 21,245 | [3]20,737 | [e]5,958 | [e]5,700 | [e]6,400 | [e]6,762 | 6,574 |
| Nauru | 1,480 | 1,359 | 1,684 | 1,358 | [3]1,508 | 570 | 523 | 648 | 523 | 581 |
| Peru | [r]12 | 29 | 3 | 13 | 12 | [r]4 | 9 | 1 | 4 | 4 |
| Philippines | 8 | 6 | 4 | (5) | -- | 2 | 2 | 1 | (5) | -- |
| Senegal | 1,699 | 1,182 | 1,521 | 1,912 | 1,702 | [e]518 | 361 | 534 | 583 | 617 |
| South Africa, Republic of | 2,718 | [r]3,161 | 2,887 | 2,585 | [3]2,421 | [e]942 | [e]1,149 | 996 | 939 | 880 |
| Sri Lanka | 15 | [e]20 | 16 | 14 | 17 | 4 | 7 | 6 | 5 | 6 |
| Sweden | 124 | 131 | 107 | 128 | [3]187 | 48 | 50 | 41 | 49 | [3]72 |
| Syria | 1,321 | 1,455 | 1,229 | 1,514 | 1,270 | 402 | 443 | 375 | 461 | 385 |
| Tanzania | -- | -- | 20 | 15 | 15 | -- | -- | 6 | 4 | 4 |
| Thailand | [r]3 | 4 | 5 | 3 | 3 | 1 | 1 | 1 | 1 | 1 |
| Togo | 2,215 | 2,800 | 2,081 | 2,696 | 2,452 | 806 | 1,005 | 755 | 979 | 890 |
| Tunisia | 4,596 | 4,196 | 5,924 | 5,346 | [3]4,530 | 1,287 | 1,213 | 1,700 | 1,554 | 1,303 |
| Turkey | 43 | [r][e]26 | 50 | 96 | 37 | 11 | 9 | 15 | 29 | 12 |
| U.S.S.R.[e] | 30,700 | 31,300 | 31,600 | 31,900 | 32,200 | 9,700 | 9,800 | 10,000 | 10,100 | 10,004 |
| United States | 53,624 | 37,414 | 42,573 | 49,197 | [3]50,835 | 16,365 | 11,504 | 13,088 | 14,889 | 15,634 |
| Vietnam[e] | 181 | 110 | 200 | 200 | 300 | 60 | 36 | 66 | 66 | 105 |
| Zimbabwe | 125 | 120 | 133 | 125 | 131 | 44 | 42 | 47 | 44 | 45 |
| Total | [r]143,001 | [r]127,385 | 139,404 | 152,488 | 151,363 | [r]43,775 | [r]39,458 | 43,750 | 47,593 | 47,365 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Basic (Thomas converter) slag: | | | | | | | | | | |
| Argentina | 1 | 1 | 1 | 1 | 1 | (7) | (7) | (7) | (7) | (7) |
| Belgium | 496 | 393 | 250 | r $^{e}$254 | 260 | 89 | 71 | 45 | 46 | 47 |
| Egypt | $^{e}$10 | 10 | 10 | 10 | 10 | $^{e}$2 | $^{e}$2 | $^{e}$2 | $^{e}$2 | 2 |
| France | 1,451 | 1,343 | 1,224 | 1,194 | 1,200 | 261 | 242 | 216 | 210 | 210 |
| Germany, Federal Republic of | 824 | 502 | 409 | $^{e}$400 | 490 | 138 | 130 | 82 | 80 | 74 |
| Luxembourg | 595 | 572 | 586 | 728 | 750 | 106 | 103 | 105 | 131 | 135 |
| United Kingdom | 4 | 4 | 4 | 4 | 4 | 1 | 1 | 1 | 1 | 1 |
| Total | 3,381 | 2,825 | 2,484 | 2,591 | 2,715 | 597 | 549 | 451 | 470 | 469 |
| Guano: | | | | | | | | | | |
| Chile | 1 | 1 | 1 | 1 | 1 | (7) | (7) | (7) | (7) | (7) |
| Kenya | -- | (7) | (7) | (7) | (7) | -- | (7) | (7) | (7) | (7) |
| Philippines | 2 | 15 | 1 | 1 | 1 | (7) | 3 | (7) | (7) | (7) |
| Seychelles Islands (exports) | $^{e}$5 | $^{e}$5 | $^{e}$5 | $^{e}$5 | 5 | 2 | 2 | 2 | 2 | 2 |
| Total | 8 | 21 | 7 | 7 | 7 | 2 | 5 | 2 | 2 | 2 |

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[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through Apr. 16, 1986. Data for major phosphate rock producing countries derived in part from the International Fertilizer Industry Association; other figures are from official country sources where available.

[2] In addition to the countries listed, Belgium and Uganda may have produced small quantities of phosphate rock, and Namibia may have produced small quantities of guano, but output is not officially reported, and available information is inadequate for formulation of reliable estimates of output levels.

[3] Reported figure.

[4] Production from Western Sahara area included with Morocco.

[5] Revised to zero.

[6] Run-of-mine ore.

[7] Less than 1/2 unit.

## TECHNOLOGY

Processing Florida phosphate rock typically involves screening and washing the matrix to separate a plus 16-mesh pebble fraction and a minus 150-mesh slime fraction, which is stored in slime ponds and slowly dewatered. The slime fraction of the Florida matrix is about one-third by weight and analyzes from 5% to 15% $P_2O_5$. In some instances, the total $P_2O_5$ in the slimes represents as much as one-third of the total $P_2O_5$ in the original matrix. If the $P_2O_5$ could be recovered profitably from impounded slimes, the life of the Florida phosphatic industry would be extended. Bureau of Mines investigators conducted batch flotation tests on the minus 150-mesh, plus 20-micrometer fraction of bulk samples from slime ponds. Concentrates were produced that analyzed 22% $P_2O_5$ with a $P_2O_5$ recovery of 60%.[8]

Demand for elemental sulfur for conversion to sulfuric acid to leach phosphate rock and produce phosphoric acid and a byproduct waste, phosphogypsum, has markedly increased during the past several years. As the selling price of sulfur increased, the feasibility of recovering sulfur from the phosphogypsum improved. Bureau of Mines process development work has showed that 99% of the calcium sulfate in the phosphogypsum could be converted to calcium sulfide by heating with coal, which provides a reducing atmosphere, at 875° C. Calcium sulfide was converted to elemental sulfur by reacting aqueous calcium sulfide slurry with ammonia and carbon dioxide to produce calcium carbonate and ammonium bisulfide. The precipitated calcium carbonate was separated by filtration and the ammonium bisulfide was oxidized with air, using a carbon catalyst, to form ammonium polysulfides. When the ammonium polysulfides were distilled, elemental sulfur precipitated and the ammonia and sulfide sulfur were condensed and recycled to the initial reaction.[9]

In the production of phosphate rock for phosphoric acid manufacture, $P_2O_5$ recovery from the phosphate matrix is limited by losses during mining and beneficiation. If the established beneficiation process could be eliminated by acidulating the matrix directly, potential recovery of the phosphate values could exceed the current level of 60% recovery. Attempts to recover phosphate values by direct acidulation had not been successful previously because impurities such as iron and aluminum were leached as well as the phosphate. These dissolved metals are difficult to separate from phosphoric acid. To overcome the problem of impurities, the Bureau of Mines investigated the use of an acid-alcohol mixture as the leaching agent. Iron and aluminum, which were insoluble in the mixture, were separated from the phosphoric acid by filtration. Phosphate recoveries as high as 88% were obtained in the laboratory.[10]

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[1] Physical scientist, Division of Industrial Minerals.

[2] Dunxun, Z. Fertilizer in China. Pres. at the 10th enlarged council meeting, International Fertilizer Industry Association (IFA), Hong Kong, Dec. 3-4, 1984, 8 pp.; available from IFA, Paris, France.

[3] European Chemical News. V. 44, No. 1160, Jan. 21, 1985, p. 23.

[4] Industrial Minerals (London). V. 211, Apr. 1985, p. 11.

[5] Phosphate Development Corp. 1985 Annual Report. Oct. 14, 1985, 25 pp.

[6] European Chemical News. V. 45, No. 1188, July 15, 1985, p. 22.

[7] Mining Magazine. June 1985, p. 571.

[8] Pederson, J. R. (ed.). Bureau of Mines Research 1985. BuMines SP 2-85, 1985, p. 64.

[9] Page 65 of work cited in footnote 8.

[10] Page 47 of work cited in footnote 8.

# Platinum-Group Metals

## By J. Roger Loebenstein[1]

World mine production of platinum-group metals (PGM) in 1985 was 8.0 million troy ounces, 94% of which was accounted for by the U.S.S.R. and the Republic of South Africa. The Republic of South Africa remained the leading producer of platinum, and the U.S.S.R. remained the leading producer of palladium.

Imports of waste and scrap, having more than doubled since 1980, remained high in 1985. The principal sources of waste and scrap were Canada and Mexico.

**Table 1.—Salient platinum-group metals[1] statistics**

(Thousand troy ounces unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Mine production[2] | 7 | 8 | 6 | 15 | W |
| Value[3] thousand dollars | [r]$1,303 | [r]$819 | [r]$1,118 | [r]$2,456 | $523 |
| Refinery production: | | | | | |
| Primary refined | 7 | 9 | 9 | 24 | 5 |
| Secondary: | | | | | |
| Nontoll-refined | 392 | 344 | 303 | [r]340 | 259 |
| Toll-refined | 1,191 | 868 | 995 | 1,157 | 1,038 |
| Total refined metal | 1,590 | 1,221 | 1,307 | [r]1,521 | 1,302 |
| Stocks, yearend: | | | | | |
| Industry (refined) | 918 | 1,107 | 943 | [r]1,319 | 1,191 |
| National Defense Stockpile: | | | | | |
| Platinum | 453 | 453 | 453 | 453 | 453 |
| Palladium[4] | 1,255 | 1,255 | 1,255 | 1,262 | 1,265 |
| Iridium[5] | 17 | [r]24 | 28 | 30 | 30 |
| Exports: | | | | | |
| Refined[6] | 651 | 439 | 446 | [r]599 | 526 |
| Total | 863 | 836 | 1,229 | 1,162 | 889 |
| Imports for consumption: | | | | | |
| Refined[6] | 2,611 | 2,150 | 2,790 | 3,928 | 3,438 |
| Total | 2,850 | 2,494 | 3,218 | 4,474 | 3,990 |
| Imports, general | [r]2,850 | 2,494 | 3,218 | [r]4,474 | 3,990 |
| Consumption (reported sales to industry) | 1,921 | 1,873 | 1,914 | [r]2,471 | 2,595 |
| Consumption, apparent[7] | 2,414 | [r]1,869 | [r]2,813 | [r]3,299 | 3,295 |
| Net import reliance[8] as a percent of apparent consumption | 83 | 81 | 89 | 89 | 92 |
| Price, dealer, average, per ounce: | | | | | |
| Platinum | $446 | $327 | $424 | $357 | $291 |
| Palladium | $95 | $67 | $136 | $148 | $107 |
| World: Mine production[9] | 6,931 | 6,424 | 6,525 | [p]7,648 | [e]7,951 |

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data.

[1] The platinum group comprises six metals: platinum, palladium, iridium, osmium, rhodium, and ruthenium.

[2] Byproduct of copper refining.

[3] Value based on dealer prices.

[4] Includes 7,200 ounces purchased in 1984 and 2,400 ounces purchased in 1985, but not added to inventory in those years.

[5] Includes 2,400 ounces purchased in 1982, another 2,400 ounces purchased in 1983, and 1,800 ounces purchased in 1984, but not added to inventory in those years.

[6] Includes both unwrought and semimanufactured.

[7] 1981-84 includes mine production plus nontoll-refined production plus refined imports for consumption minus refined exports plus or minus changes in Government and industry stocks. 1985 mine production excluded to avoid disclosing company proprietary data.

[8] Refined imports for consumption minus refined exports plus or minus changes in Government and industry stocks.

[9] 1985 total excludes U.S. mine production in order to avoid disclosing company proprietary data.

The price of osmium remained fairly stable in 1985, after increasing almost sevenfold in 1984. Reportedly, industry sources suggested that the rapid price increase was the result of a combination of only a modest increase in demand base and because of the small size of the industry.

**Domestic Data Coverage.**—Domestic production data for PGM are developed by the Bureau of Mines from a voluntary survey of U.S. refiners. Of the 17 refiners to which a survey request was sent, 16 responded, representing an estimated 45% of the total refined metal production shown in tables 1 and 2. Production of refined metal for the one nonrespondent was estimated using reported prior year production levels.

**Legislation and Government Programs.**—The General Services Administration purchased 2,400 ounces of grade B (99.8% minimum) palladium sponge for the National Defense Stockpile in January 1985.

On July 8, the President approved the National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict that would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. The status of platinum, palladium, and iridium was deferred until further detailed studies could be made. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

## DOMESTIC PRODUCTION

ASARCO Incorporated and Kennecott produced platinum and palladium as byproducts of copper refining. Secondary metal was refined by about 17 firms, mostly on the east and west coasts. Most PGM scrap was refined on a toll basis. The largest scrap processor in the United States was Johnson Matthey Inc.

U.S. Metals Refining Co. in Carteret, NJ, a subsidiary of AMAX Copper Inc., began phasing out its precious metals scrap refining and copper smelting and refining operations. The phaseout was expected to be complete by the end of 1986. The company was a major toll refiner of PGM and a small refiner of byproduct PGM from copper refineries. The company's decision was reportedly based on continuing losses from operations at the plant combined with the poor economic outlook for secondary smelting and refining activities in the United States.[2]

Anaconda Minerals Co. sold its one-third partnership interest in Stillwater Mining Co. (SMC) to Lac Minerals Ltd., Toronto, Canada, for $15 million. SMC is a partnership between Chevron Resources Inc., Manville International Corp., and Lac Minerals, that was engaged in developing a palladium-platinum mine at the Stillwater Complex in Montana. In September, SMC contracted American Mine Services Inc. to conduct underground test mining over a 12-month period. In December, the U.S. Forest Service approved the company's operating permit, and the State of Montana issued an Environmental Impact Statement for the project. According to the company, if ore grades prove favorable, construction of the mine could begin in 1986 and production could start in 1987. Initially, SMC would process 500 metric tons of ore per day, yielding 75,000 ounces of palladium and 25,000 ounces of platinum per year, rates that could be doubled later.

The Bureau of Mines reported that a palladium-platinum mine in the Stillwater Complex in Montana could yield a rate of return approaching 20%. The Bureau estimated costs for PGM from the Stillwater Complex to be potentially 15% lower than for PGM recovered from the Merensky Reef in the Republic of South Africa, based on a 2,500-ton-per-day mining system at Stillwater for both PGM and chromite ores. However, the revenue per ounce of PGM recovered would be 33.5% less than is typical for the South African PGM producers, owing mostly to the much higher palladium content of the Stillwater ores.[3]

Engelhard Corp. began construction of a custom catalyst plant near Seneca, SC. The new $25 million plant will replace the company's Newark, NJ, plant. The catalysts produced will be based on palladium, platinum, rhodium, and ruthenium.

Handy & Harman opened a new precious

metals recovery plant at a cost of $7 million in South Windsor, CT. The plant will specialize in processing electronic scrap from the computer industry.[4]

## Table 2.—Platinum-group metals refined in the United States

(Troy ounces)

| | Platinum | Palladium | Iridium | Osmium | Rhodium | Ruthenium | Total |
|---|---|---|---|---|---|---|---|
| PRIMARY METAL | | | | | | | |
| Nontoll-refined: | | | | | | | |
| 1981 | 1,005 | 4,602 | -- | -- | -- | -- | 5,607 |
| 1982 | 947 | 6,131 | -- | -- | -- | -- | 7,078 |
| 1983 | 879 | 5,005 | -- | -- | -- | -- | 5,884 |
| 1984 | 1,430 | 13,003 | -- | -- | -- | -- | 14,433 |
| 1985 | 524 | 3,463 | -- | -- | -- | -- | 3,987 |
| Toll-refined: | | | | | | | |
| 1981 | 235 | 934 | -- | -- | -- | -- | 1,169 |
| 1982 | 434 | 1,421 | -- | -- | -- | -- | 1,855 |
| 1983 | 1,150 | 2,026 | -- | -- | -- | -- | 3,176 |
| 1984 | 1,153 | 4,895 | 1,000 | 250 | -- | 2,000 | 9,298 |
| 1985 | 1,100 | -- | -- | -- | -- | -- | 1,100 |
| SECONDARY METAL | | | | | | | |
| Nontoll-refined: | | | | | | | |
| 1981 | 187,883 | 185,764 | 3,318 | 64 | 11,317 | 3,291 | 391,637 |
| 1982 | 190,249 | 139,286 | 2,896 | -- | 11,302 | 427 | 344,160 |
| 1983 | 118,579 | 177,816 | 2,357 | -- | 3,663 | 750 | 303,165 |
| 1984 | $^{r}$89,702 | $^{r}$243,347 | 735 | 27 | $^{r}$3,668 | 2,047 | $^{r}$339,526 |
| 1985 | 52,382 | 201,416 | 252 | -- | 3,126 | 1,474 | 258,650 |
| Toll-refined: | | | | | | | |
| 1981 | 520,717 | 607,397 | 7,826 | 1,865 | 34,870 | 18,471 | 1,191,146 |
| 1982 | 393,832 | 430,564 | 10,108 | 885 | 26,693 | 6,301 | 868,383 |
| 1983 | 433,700 | 456,732 | 5,820 | 925 | 41,624 | 55,788 | 994,589 |
| 1984 | 524,158 | 568,489 | 7,826 | 49 | 37,584 | 19,288 | 1,157,394 |
| 1985 | 490,571 | 490,647 | 7,007 | 3 | 36,336 | 13,356 | 1,037,920 |
| 1984 TOTALS | | | | | | | |
| Total primary | 2,583 | 17,898 | 1,000 | 250 | -- | 2,000 | 23,731 |
| Total secondary | $^{r}$613,860 | $^{r}$811,836 | 8,561 | 76 | $^{r}$41,252 | 21,335 | $^{r}$1,496,920 |
| Total refined metal | $^{r}$616,443 | $^{r}$829,734 | 9,561 | 326 | $^{r}$41,252 | 23,335 | $^{r}$1,520,651 |
| 1985 TOTALS | | | | | | | |
| Total primary | 1,624 | 3,463 | -- | -- | -- | -- | 5,087 |
| Total secondary | 542,953 | 692,063 | 7,259 | 3 | 39,462 | 14,830 | 1,296,570 |
| Total refined metal | 544,577 | 695,526 | 7,259 | 3 | 39,462 | 14,830 | 1,301,657 |

$^{r}$Revised.

## CONSUMPTION AND USES

PGM were used principally in catalysts for the control of automobile and industrial plant emissions; in reforming catalysts used to upgrade the octane rating of gasolines; in catalysts used to produce acids, organic chemicals, and pharmaceuticals; in bushings for making glass fibers used in fiber-reinforced-plastic and other materials; in electrical contacts; in capacitors; in conductive and resistive films used in electronic circuits; and in dental alloys used for making crowns and bridges.

In electronic applications, ruthenium was the principal PGM used in thick film resistors, while palladium was the principal PGM used in thick film conductors, multilayer ceramic capacitors, and connectors.[5]

For glass applications, the greatest amounts of PGM, specifically platinum, rhodium, and palladium, were used in the production of textile or continuous filament glass fiber.

### Table 3.—Platinum-group metals[1] sold to consuming industries in the United States

(Troy ounces)

| Year and industry | Platinum | Palladium | Iridium | Osmium | Rhodium | Ruthenium | Total |
|---|---|---|---|---|---|---|---|
| 1981 | 872,639 | 889,186 | 8,416 | 663 | 62,110 | 87,658 | 1,920,672 |
| 1982 | 780,146 | 926,304 | 10,600 | 1,358 | 49,915 | 104,930 | 1,873,253 |
| 1983 | 796,716 | 921,829 | 5,023 | 1,389 | 44,225 | 144,777 | 1,913,959 |
| 1984: | | | | | | | |
| Automotive[2] | 722,000 | 286,000 | 217 | -- | 63,000 | 1,035 | 1,072,252 |
| Chemical | 73,496 | 78,600 | 735 | 10 | 4,631 | 24,743 | 182,215 |
| Dental and medical | 18,644 | 347,043 | 381 | 1,062 | 427 | 62 | 367,619 |
| Electrical | [r]99,155 | [r]389,695 | 1,514 | -- | [r]7,461 | [r]54,155 | [r]551,980 |
| Glass | 12,184 | 10 | 106 | -- | 2,941 | -- | 15,241 |
| Jewelry and decorative | [r]9,549 | [r]6,884 | 1,173 | -- | [r]2,116 | [r]813 | [r]20,535 |
| Petroleum | 28,045 | 92,134 | -- | -- | 11 | 600 | 120,790 |
| Miscellaneous | 66,154 | 57,134 | 2,991 | -- | 6,666 | 7,211 | 140,156 |
| Total | [r]1,029,227 | [r]1,257,500 | 7,117 | 1,072 | [r]87,253 | [r]88,619 | [r]2,470,788 |
| 1985: | | | | | | | |
| Automotive[2] | 811,000 | 295,000 | 287 | -- | 74,000 | 1,035 | 1,181,322 |
| Chemical | 85,227 | 63,236 | 966 | 17 | 4,096 | 19,090 | 172,632 |
| Dental and medical | 24,563 | 350,678 | 645 | 868 | 352 | 96 | 377,202 |
| Electrical | 115,840 | 300,677 | 1,843 | -- | 5,665 | 50,956 | 474,981 |
| Glass | 20,651 | 416 | 177 | -- | 2,467 | 14 | 23,725 |
| Jewelry and decorative | 16,040 | 7,096 | 1,889 | -- | 2,222 | 661 | 27,908 |
| Petroleum | 28,771 | 80,940 | -- | -- | 31 | -- | 109,742 |
| Miscellaneous | 115,722 | 87,970 | 4,857 | -- | 5,419 | 13,722 | 227,690 |
| Total | 1,217,814 | 1,186,013 | 10,664 | 885 | 94,252 | 85,574 | 2,595,202 |

[r] Revised.

[1] Comprises primary and nontoll-refined secondary metals.

[2] Platinum, palladium, and rhodium sales to the automotive industry are estimated based on purchases by the major U.S. automobile manufacturers.

## STOCKS

In addition to the reported stocks held by refiners, importers, and dealers, end users of PGM held sizable quantities of PGM that were not reported to the Bureau of Mines. Overall, PGM stocks declined 10% in 1985; only the stocks of iridium and rhodium increased.

### Table 4.—Refiner, importer, and dealer stocks of refined platinum-group metals[1] in the United States, December 31

(Troy ounces)

| Year | Platinum | Palladium | Iridium | Osmium | Rhodium | Ruthenium | Total |
|---|---|---|---|---|---|---|---|
| 1981 | 401,389 | 398,933 | 16,819 | 37 | 43,355 | 57,645 | 918,178 |
| 1982 | 604,632 | 384,184 | 13,348 | 138 | 40,562 | 63,764 | 1,106,628 |
| 1983 | 433,457 | 412,178 | 16,944 | 489 | 51,107 | 28,973 | 943,148 |
| 1984 | [r]648,130 | [r]524,924 | [r]19,600 | 1,302 | [r]53,120 | [r]71,571 | [r]1,318,647 |
| 1985 | 564,363 | 478,348 | 20,301 | 262 | 60,947 | 67,093 | 1,191,314 |

[r] Revised.

[1] Includes metal in depositories of the New York Mercantile Exchange (NYMEX); on Dec. 27, 1985, this comprised 270,500 troy ounces of platinum and 111,400 troy ounces of palladium.

## PRICES

Throughout the year, dealer prices for platinum and palladium decreased. Average dealer prices for rhodium and osmium increased significantly in 1985, iridium and ruthenium remained about the same as in 1984.

Impala Platinum Holdings Ltd. of the Republic of South Africa was the sole producer retaining producer price quotes for platinum, palladium, rhodium, and iridium, following a decision in 1984 by Rustenburg Platinum Holdings Ltd. to suspend all of its producer price quotes for PGM.[6]

### Table 5.—Average producer and dealer prices[1] of platinum-group metals

(Dollars per troy ounce)

| | Platinum | | Palladium | | Rhodium | | Iridium | | Ruthenium | | Osmium | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Producer | Dealer | Producer | Dealer | Producer | Dealer | Producer | Dealer | Producer | Dealer | Producer | Dealer |
| 1981 | 475 | 446 | 130 | 95 | 641 | 498 | 600 | 529 | 45 | 32 | 150 | 130 |
| 1982 | 475 | 327 | 110 | 67 | 600 | 323 | 600 | 359 | 45 | 26 | 137 | 130 |
| 1983 | 475 | 424 | 130 | 136 | 600 | 312 | 600 | 309 | 45 | 28 | 110 | 132 |
| 1984: | | | | | | | | | | | | |
| January | 475 | 377 | 130 | 157 | 600 | 346 | 600 | 331 | 45 | 45 | (2) | 140 |
| February | 475 | 389 | 130 | 160 | 600 | 354 | 600 | 345 | 45 | 55 | (2) | 140 |
| March | 475 | 399 | 150 | 161 | 600 | 382 | 600 | 350 | 45 | 62 | (2) | 151 |
| April | 475 | 392 | 150 | 160 | 600 | 468 | 600 | 391 | 45 | 63 | (2) | 179 |
| May | 475 | 386 | 150 | 155 | 600 | 551 | 600 | 439 | 45 | 65 | (2) | 272 |
| June | 475 | 381 | 150 | 153 | 600 | 655 | 600 | 468 | 45 | 80 | (2) | 364 |
| July | 475 | 341 | 150 | 138 | 600 | 687 | 600 | 496 | (3) | 152 | (2) | 420 |
| August | 475 | 338 | 150 | 137 | 600 | 721 | 600 | 483 | (3) | 145 | (2) | 432 |
| September | 475 | 326 | 150 | 138 | 600 | 717 | 600 | 468 | (3) | 143 | (2) | 692 |
| October | 475 | 324 | 150 | 138 | 600 | 759 | 600 | 438 | (3) | 137 | (2) | 873 |
| November | 475 | 327 | 150 | 146 | 750 | 799 | 600 | 424 | (3) | 134 | (2) | 900 |
| December | 475 | 303 | 150 | 134 | 750 | 846 | 600 | 449 | (3) | 155 | (2) | 900 |
| Average | 475 | 357 | 147 | 148 | 625 | 607 | 600 | 424 | (3) | 103 | (2) | 455 |
| 1985: | | | | | | | | | | | | |
| January | 475 | 274 | 150 | 121 | 766 | 948 | 600 | 458 | (3) | 158 | (2) | 935 |
| February | 475 | 269 | 150 | 124 | 1,000 | 1,086 | 600 | 546 | (3) | 160 | (2) | 950 |
| March | 475 | 260 | 143 | 113 | 1,000 | 1,018 | 600 | 496 | (3) | 151 | (2) | 956 |
| April | 475 | 282 | 120 | 112 | 1,000 | 1,003 | 600 | 471 | (3) | 143 | (2) | 1,000 |
| May | 475 | 269 | 120 | 124 | 1,000 | 828 | 600 | 435 | (3) | 101 | (2) | 1,000 |
| June | 475 | 264 | 120 | 93 | 880 | 658 | 600 | 404 | (3) | 80 | (2) | 1,000 |
| July | 475 | 268 | 120 | 94 | 800 | 643 | 600 | 378 | (3) | 68 | (2) | 1,000 |
| August | 475 | 308 | 120 | 103 | 1,000 | 812 | 600 | 409 | (3) | 73 | (2) | 861 |
| September | 475 | 309 | 120 | 99 | 880 | 933 | 600 | 416 | (3) | 70 | (2) | 807 |
| October | 475 | 323 | 120 | 101 | 851 | 1,016 | 600 | 414 | (3) | 69 | (2) | 818 |
| November | 475 | 334 | 120 | 100 | 800 | 1,078 | 600 | 410 | (3) | 70 | (2) | 825 |
| December | 475 | 334 | 120 | 95 | 1,003 | 1,119 | 600 | 414 | (3) | 70 | (2) | 830 |
| Average | 475 | 291 | 127 | 107 | 915 | 929 | 600 | 438 | (3) | 101 | (2) | 915 |

[1] Average prices calculated at the low end of the range and rounded to the nearest dollar.
[2] Producer price suspended on Jan. 13, 1984.
[3] Producer price suspended on June 7, 1984.

Source: Metals Week.

Trading volume on the New York Mercantile Exchange in futures contracts for 1983-85, is shown in the following tabulation:

| | Platinum[1] | Palladium[2] |
|---|---|---|
| 1983 | 1,053,282 | 241,224 |
| 1984 | 571,127 | 159,019 |
| 1985 | 693,256 | 133,223 |

[1] 50 troy ounces per contract.
[2] 100 troy ounces per contract.

## FOREIGN TRADE

The major sources for imports of PGM, in descending order, were the Republic of South Africa, the United Kingdom, the U.S.S.R., Canada, and Belgium-Luxembourg. Some of the imports from the United Kingdom originated from ore mined in the Republic of South Africa, and some of the imports from the Netherlands and other European countries may have originated from ore mined in the U.S.S.R. The major recipients of exports, in descending order, were Japan, the United Kingdom, and Canada. The United States exported sizable quantities of PGM-bearing scrap, some of which was concentrated from used automobile catalytic converters.

## Table 6.—U.S. exports of platinum-group metals, by year and country

| Year and country | Ores and concentrates (troy ounces) | Waste, scrap, and sweepings (troy ounces) | Metal not rolled (troy ounces) | | | Metal rolled (troy ounces) | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Platinum | Palladium | Other platinum group | Platinum | Other platinum group | Troy ounces | Value (thousands) |
| 1981 | 8,246 | 204,180 | 327,328 | 149,794 | 81,848 | 63,866 | 28,103 | 863,365 | $301,890 |
| 1982 | 8,870 | 388,437 | 125,581 | 167,397 | 84,832 | 50,224 | 10,535 | 835,876 | 182,460 |
| 1983 | 31,827 | 751,140 | 138,928 | 155,607 | 71,289 | 45,671 | 34,292 | 1,228,754 | 309,917 |
| 1984 | $^{r}$40,920 | 522,425 | 177,401 | 182,692 | $^{r}$167,635 | 43,484 | 27,475 | $^{r}$1,162,032 | $^{r}$274,775 |
| 1985: | | | | | | | | | |
| Australia | -- | 147 | 352 | 1,659 | 1,342 | -- | 91 | 3,591 | 770 |
| Belgium-Luxembourg | 40 | 75,554 | 1,929 | 1,775 | 170 | -- | 87 | 79,555 | 16,158 |
| Brazil | -- | -- | 961 | 2,844 | -- | 347 | 4 | 4,156 | 763 |
| Canada | 1,942 | 54,049 | 1,017 | 20,935 | 24,868 | 243 | 621 | 108,675 | 23,477 |
| China | -- | -- | 1,654 | 2,572 | -- | -- | -- | 4,226 | 663 |
| France | -- | 1,092 | 760 | 18,560 | 11,564 | 1,642 | 1,064 | 34,682 | 2,815 |
| Germany, Federal Republic of | -- | 19,303 | 923 | 30,554 | 1,267 | 58 | 119 | 52,224 | 8,573 |
| Greece | -- | -- | -- | 752 | 141 | -- | -- | 898 | 148 |
| Hong Kong | -- | -- | 6,419 | 652 | 141 | -- | -- | 7,212 | 1,842 |
| Israel | -- | -- | 5 | 8 | 860 | -- | 69 | 942 | 191 |
| Italy | -- | 2,393 | 452 | 1,480 | 2,445 | 656 | 198 | 7,624 | 1,775 |
| Japan | 716 | 7,043 | 159,737 | 73,028 | 19,206 | 1,109 | 5,613 | 266,452 | 64,584 |
| Korea, Republic of | 131 | 136 | 78 | 715 | 1,506 | 176 | 24 | 2,766 | 383 |
| Netherlands | -- | -- | 3,694 | 1,652 | 482 | 100 | 24,323 | 30,251 | 3,906 |
| Singapore | -- | 10,500 | 200 | 5,045 | 22 | 2 | -- | 15,769 | 583 |
| South Africa, Republic of | -- | 2 | -- | 226 | 1,078 | -- | -- | 1,306 | 200 |
| Spain | -- | 401 | -- | 1,200 | 97 | -- | -- | 1,698 | 196 |
| Sweden | -- | 5,419 | -- | 60 | 4,202 | -- | -- | 9,681 | 2,482 |
| Switzerland | -- | -- | -- | 3,779 | 10,013 | -- | 22 | 13,814 | 3,638 |
| Taiwan | -- | -- | 198 | 4,005 | 12 | -- | -- | 4,215 | 563 |
| United Kingdom | 512 | 182,210 | 3,876 | 41,457 | 7,069 | 104 | 3,371 | 238,599 | 52,067 |
| Uruguay | 607 | -- | 9 | 373 | 161 | -- | -- | 1,150 | 158 |
| Other | 19 | 168 | 223 | 2,295 | 1,081 | 89 | 295 | 4,170 | 1,206 |
| Total | 3,967 | 358,417 | 182,487 | 215,626 | 87,727 | 4,526 | 35,901 | 888,651 | 187,161 |

$^{r}$Revised.

Source: Bureau of the Census.

## Table 7.—U.S. imports for consumption of platinum-group metals, by year and country

| Year and country | Unwrought (troy ounces) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Platinum grains and nuggets | Platinum sponge | Palladium | Iridium | Osmium | Osmiridium | Rhodium | Ruthenium | Unspecified combinations | Platinum-group metals from precious metal ores | Sweepings, waste, and scrap |
| 1981 | 1,891 | 888,995 | 1,114,313 | 11,110 | 850 | 9,309 | 73,738 | 180,438 | 32,736 | 1,442 | 235,379 |
| 1982 | 3,298 | 689,647 | 1,039,210 | 19,402 | 1,600 | 5,576 | 68,968 | 133,798 | 14,880 | 1,373 | 339,095 |
| 1983 | 8,513 | 1,005,208 | 1,223,951 | 23,266 | 1,747 | 848 | 119,958 | 163,623 | 18,143 | 2,137 | 417,431 |
| 1984 | 19,786 | 1,527,841 | 1,795,939 | 18,225 | 1,630 | 150 | 155,671 | 198,257 | 8,822 | -- | 526,738 |
| 1985: | | | | | | | | | | | |
| Australia | 39 | 1,513 | 4,502 | -- | -- | -- | -- | -- | -- | -- | 2,697 |
| Belgium-Luxembourg | 1,384 | 36,063 | 134,277 | -- | 50 | -- | 570 | -- | -- | -- | 48,597 |
| Canada | -- | 14,669 | 83,106 | 40 | -- | -- | 3,288 | 500 | 173 | -- | 187,604 |
| Colombia | 8,730 | 11,700 | -- | -- | -- | -- | -- | -- | 1,800 | -- | 26,487 |
| Germany, Federal Republic of | 552 | 36,026 | 46,864 | 1,001 | 3 | -- | 3,999 | 446 | -- | -- | 52,982 |
| Italy | -- | 10,461 | 6,450 | -- | -- | -- | -- | -- | -- | -- | -- |
| Japan | 500 | 2,293 | 13,349 | 230 | -- | -- | 500 | 13,557 | -- | -- | 803 |
| Mexico | -- | -- | 2,000 | -- | -- | -- | -- | -- | -- | -- | 130,083 |
| Netherlands | -- | 52,539 | 66,049 | 1,279 | 2,552 | -- | 6,837 | 2,089 | -- | -- | 2,648 |
| Saudi Arabia | -- | 23,006 | 12,250 | 532 | 10 | -- | 2,524 | 2,000 | -- | -- | 1,047 |
| South Africa, Republic of | 590 | 1,018,258 | 579,628 | 12,415 | 308 | -- | 115,484 | 82,947 | 3,973 | -- | 3,427 |
| Sweden | -- | 29 | -- | -- | -- | -- | 9 | -- | -- | -- | 19,417 |
| Switzerland | -- | 13,000 | 16,489 | 100 | -- | -- | 156 | 500 | -- | -- | -- |
| Taiwan | -- | -- | 457 | -- | -- | -- | -- | -- | -- | -- | 35,624 |
| U.S.S.R | 1,717 | 14,938 | 234,497 | 990 | -- | -- | 13,098 | 1,911 | 664 | -- | -- |
| United Kingdom | 7,010 | 226,490 | 187,601 | 4,105 | 2,230 | -- | 50,634 | 57,937 | 3,413 | -- | 434 |
| Other | 305 | 3,660 | 9,291 | 280 | -- | -- | 3,929 | 1,000 | 307 | 218 | 18,874 |
| Total | 20,827 | 1,464,645 | 1,396,810 | 20,972 | 5,153 | -- | 201,028 | 162,887 | 10,330 | 218 | 530,724 |

Table 7.—U.S. imports for consumption of platinum-group metals, by year and country—Continued

| Year and country | Semimanufactured (troy ounces) | | | | | Platinum-group metals in materials not elsewhere specified (troy ounces) | Total | |
|---|---|---|---|---|---|---|---|---|
| | Platinum | Palladium | Iridium | Rhodium | Unspecified combinations | | Troy ounces | Value (thousands) |
| 1981 | 179,321 | 116,548 | 248 | 1,733 | 3 | 1,563 | 2,849,617 | $800,256 |
| 1982 | 114,028 | 60,760 | 907 | 1,005 | 159 | -- | 2,493,706 | 553,985 |
| 1983 | 109,376 | 108,247 | 218 | 11,245 | -- | 4,116 | 3,218,022 | 752,756 |
| 1984 | 60,140 | 158,012 | 164 | 2,389 | 10 | 332 | 4,474,106 | 1,118,088 |
| 1985: | | | | | | | | |
| Australia | -- | -- | -- | -- | -- | -- | 8,751 | 2,050 |
| Belgium-Luxembourg | -- | -- | -- | -- | -- | 107 | 221,048 | 50,300 |
| Canada | 222 | 28 | -- | -- | -- | 86 | 289,716 | 29,567 |
| Colombia | -- | -- | -- | -- | -- | 1,800 | 50,517 | 14,160 |
| Germany, Federal Republic of | 116 | 16,282 | -- | 35 | -- | -- | 158,306 | 22,844 |
| Italy | -- | -- | -- | -- | -- | -- | 16,911 | 3,937 |
| Japan | 5,045 | 948 | -- | -- | -- | -- | 37,225 | 6,279 |
| Mexico | -- | -- | -- | -- | -- | -- | 132,083 | 1,519 |
| Netherlands | 301 | 982 | -- | -- | -- | -- | 135,276 | 39,866 |
| Saudi Arabia | -- | -- | -- | -- | -- | -- | 41,369 | 14,466 |
| South Africa, Republic of | 3,767 | -- | -- | -- | -- | 4,955 | 1,825,752 | 586,276 |
| Sweden | -- | -- | -- | -- | -- | -- | 19,455 | 8,564 |
| Switzerland | 9,931 | 600 | -- | -- | -- | -- | 40,776 | 12,080 |
| Taiwan | -- | -- | -- | -- | -- | -- | 36,081 | 445 |
| U.S.S.R. | 5,548 | 38,495 | 1,929 | -- | -- | -- | 313,787 | 48,788 |
| United Kingdom | 53,276 | 27,157 | 1,194 | 110 | -- | -- | 621,591 | 173,768 |
| Other | -- | -- | 577 | -- | 1,480 | 1,029 | 40,950 | 10,783 |
| Total | 78,206 | 84,492 | 3,700 | 145 | 1,480 | 7,977 | 3,989,594 | 1,025,692 |

Source: Bureau of the Census.

**Table 8.—Estimated U.S. imports of platinum and palladium, by year and country[1]**

(Thousand troy ounces)

| Country | Platinum 1984 | Platinum 1985 | Palladium 1984 | Palladium 1985 |
|---|---|---|---|---|
| South Africa, Republic of | 1,043 | 1,029 | 587 | 584 |
| U.S.S.R | 20 | 23 | 495 | 273 |
| United Kingdom | 300 | 288 | 391 | 216 |
| Other | 411 | 395 | 824 | 759 |
| Total[2] | 1,774 | 1,735 | 2,296 | 1,833 |

[1] This table is based on the figures shown in table 7. Estimates are based on the explicit categories of palladium plus estimates of the metal content in the following categories: unspecified combinations, ores, and scrap, and materials not elsewhere specified.

[2] Data may not add to totals shown because of independent rounding.

## WORLD REVIEW

PGM were mined in 10 countries in 1985. The Republic of South Africa and the U.S.S.R. together accounted for 94% of world mine production. Three companies in the Republic of South Africa produced PGM from platinum ores, while the U.S.S.R. and two companies in Canada produced PGM from nickel-copper ores. Production of the principal metals of the group, platinum and palladium, was 3.4 million ounces and 3.7 million ounces, respectively, of which the U.S.S.R. produced an estimated 950 million ounces of platinum and 2.5 million ounces of palladium.

World supply and demand in market economy countries for palladium were well balanced in 1985, while there was a slight deficit in supply for platinum, as shown in the tabulation below in units of thousand ounces:

|  | Platinum | Palladium |
|---|---|---|
| SUPPLY[1] |  |  |
| Mine production: |  |  |
| South Africa, Republic of[e] | 2,257 | 962 |
| Canada | 150 | 158 |
| Other | 38 | 67 |
| Total | 2,445 | 1,187 |
| Secondary, old scrap: |  |  |
| United States | 52 | 201 |
| Japan[2] | 29 | 195 |
| Other[3] | 51 | 150 |
| Total | 132 | 546 |
| Soviet sales[3] | 200 | 1,360 |
| Total | 2,777 | 3,093 |
| DEMAND[1] |  |  |
| Industrial: |  |  |
| Japan[2] | 1,280 | 1,270 |
| United States | 1,218 | 1,186 |
| Other[3] | 413 | 650 |
| Total | 2,911 | 3,106 |

[e] Estimated.

[1] Market economy countries.

[2] Sumitomo Corp. Precious Metals Market in Japan. 16th ed., Feb. 1986, 18 pp.

[3] J. Aron & Co., Goldman, Sachs & Co. Commodity Market Perspectives—Platinum Group Metals. Dec. 1985, 48 pp.

According to a recent publication by Johnson Matthey P.L.C., the demand in market economy countries for platinum used in automobiles, jewelry, glass fiber bushings, and investment bars and coins increased in 1985 from the level of 1984.[7] Factors that may have influenced investors to purchase additional platinum were a strike by South African gold miners in September and, a month later, a U.S. Government ban on the importation of South African Krugerrand gold coins. In view of the widening interest in platinum as an investment, an industry organization called the Platinum Guild (USA) was formed in September to disseminate information concerning the investment benefits of platinum ownership. In Europe, Ayrton Metals Inc., the marketing agent for Impala, announced plans to begin selling fractional ounce platinum "noble" coins, equal to one-tenth of the current 1-ounce coin weight.[8] The platinum "noble" had been introduced in November 1983 in Switzerland, the Federal Republic of Germany, and the United Kingdom, and had proven to be popular among investors.

In June, the European Economic Community (EEC) agreed to introduce restrictions on automobile emissions to be implemented in stages between 1988 and 1993.[9] Currently, the only way to meet the EEC standard, which is roughly equivalent to the current U.S. standard, is by using catalytic exhaust converters. The EEC standard was expected to have a major impact on world demand for platinum and rhodium, and a lesser impact on demand for palladium, over the next decade.

**Canada.**—Among companies exploring and/or developing PGM deposits were Fleck Resources Ltd. in Marathon, Ontario; Boston Bay Mines Ltd. near Thunder Bay, Ontario; Nexus Resource Corp. on Vancouver Island, British Columbia; and Dumont Nickel Corp. in Quebec.[10]

**Japan.**—Imports totaled about 1.3 million ounces of platinum, primarily from the Republic of South Africa, and about 1.1 million ounces of palladium, primarily from the U.S.S.R. Imports of platinum increased, while imports of palladium decreased from the amounts reported in 1984.[11]

Consumption of platinum in jewelry increased, and consumption of palladium in electrical uses decreased in 1985. Estimated total consumption of platinum and palladium in Japan, in thousand troy ounces, was reported as follows:

| | Platinum | Palladium |
|---|---|---|
| Automotive | 170 | 100 |
| Chemical | 120 | 400 |
| Dental | -- | 210 |
| Electrical | 150 | 470 |
| Jewelry | 630 | 60 |
| Miscellaneous[1] | 210 | 30 |
| Total | 1,280 | 1,270 |

[1]Glass is included in "Miscellaneous" category for platinum.

Source: Sumitomo Corp.

**South Africa, Republic of.**—Matthey Rustenburg Refiners Ltd., jointly owned by Johnson Matthey P.L.C. and Rustenburg Platinum, reportedly decided to build a new Solvex PGM refining plant in the Republic of South Africa. The plant, which was expected to be completed by 1990, was to be modeled after the Royston, United Kingdom, plant and would treat 100% of Rustenburg's primary PGM output. The Royston plant would then be converted into a PGM scrap refinery.[12]

Western Platinum Ltd., the smallest of the three PGM producers in the Republic of South Africa, sent its last shipment of PGM-bearing nickel-copper matte to Norway for refining by Falconbridge Nickel Ltd. Western expected its newly commissioned $9 million nickel-copper-cobalt refinery, at its Marikana Mine in the Transvaal, to greatly speed up the recovery of base metals and PGM, as well as reduce shipping costs. Previously, the PGM included in the matte shipped to Norway were returned in the form of a concentrate for final platinum-palladium refining in the Republic of South Africa. Western completed expansion of its precious metals plant at Brakpan, acquiring the capacity to refine the minor PGM as well as platinum and palladium. Falconbridge, which owns 25% of Western, was to continue its exclusive marketing agreement with Western.[13]

### Table 9.—Platinum-group metals: World production, by country[1]

(Troy ounces)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Australia, metal content, from domestic nickel ore:[3] | | | | | |
| Palladium | 12,896 | 13,379 | [e]12,000 | [e]12,000 | 13,600 |
| Platinum | 2,093 | 2,388 | [e]1,900 | [r] [e]1,900 | 2,400 |
| Canada: Platinum-group metals from nickel ore | 382,658 | 228,425 | 223,925 | 348,216 | 350,000 |
| Colombia: Placer platinum | 14,804 | 11,886 | 10,303 | 10,106 | 11,400 |
| Ethiopia: Placer platinum[e] | 125 | 125 | 125 | 125 | 125 |
| Finland: | | | | | |
| Palladium | 1,993 | 4,662 | 2,283 | 1,093 | 1,100 |
| Platinum | 1,608 | 4,147 | 2,186 | 1,061 | 1,100 |
| Japan, metal recovered from nickel-copper ores:[4] | | | | | |
| Palladium | 25,748 | 27,862 | 37,122 | 33,802 | [5]43,703 |
| Platinum | 10,521 | 15,411 | 21,460 | 19,523 | [5]22,216 |
| South Africa, Republic of: Platinum-group metals from platinum ore[e] [6] | 3,110,000 | 2,600,000 | 2,600,000 | [r]3,500,000 | 3,700,000 |
| U.S.S.R.: Placer platinum and platinum-group metals recovered from nickel-copper ores[e] | 3,350,000 | 3,500,000 | 3,600,000 | 3,700,000 | 3,800,000 |
| United States: Placer platinum and platinum-group metals from gold-copper ores | 7,318 | 8,033 | 6,257 | 14,635 | W |
| Yugoslavia: | | | | | |
| Palladium | 3,119 | 2,893 | 2,926 | [r] [e]3,100 | 3,300 |
| Platinum | 482 | 418 | 193 | [r] [e]200 | 250 |
| Zimbabwe: | | | | | |
| Palladium | 5,200 | 2,765 | 2,395 | 1,222 | 1,300 |
| Platinum | 2,300 | 1,704 | 1,695 | 772 | 800 |
| Total | 6,930,865 | [r]6,424,098 | 6,524,770 | 7,647,755 | 7,951,294 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; excluded from "Total."

[1] Table includes data available through May 20, 1986. Platinum-group metal production by the Federal Republic of Germany, Norway, and the United Kingdom is not included in this table because the production is derived wholly from imported metallurgical products and to include it would result in double counting.

[2] In addition to the countries listed, China, Indonesia, Papua New Guinea, and the Philippines are believed to produce platinum-group metals, and several other countries may also do so, but output is not reported quantitatively, and there is no reliable basis for the formulation of estimates of output levels. However, a part of this output not specifically reported by country is presumably included in this table credited to Japan. (See footnote 4.)

[3] Partial figure; excludes platinum-group metals recovered in other countries from nickel ore of Australian origin; however, a part of this output may be credited to Japan. (See footnote 4.)

[4] Japanese figures do not refer to Japanese mine production, but rather represent Japanese smelter-refinery recovery from ores originating in a number of countries; this output cannot be credited to the country of origin because of a lack of data. Countries producing and exporting such ores to Japan include (but are not necessarily limited to) Australia, Canada, Indonesia, Papua New Guinea, and the Philippines. Output from ores of Australian, Indonesian, Papua New Guinean, and the Philippine origin are not duplicative, but output from Canadian material might duplicate a part of reported Canadian production.

[5] Reported figure.

[6] Includes osmiridium produced in gold mines.

## TECHNOLOGY

The Office of Technology Assessment, U.S. Congress, published a report on PGM and three other critical metals.[14] The purpose of the report was to probe ways to reduce U.S. import dependence on the Republic of South Africa and the U.S.S.R. With regard to PGM, the report concluded that the United States could conserve PGM by increasing recycling of used automobile catalytic converters to recover 500,000 ounces of PGM annually by 1995. In addition, the study concluded that development of the Stillwater Complex deposit in Montana could produce about 175,000 ounces of PGM annually, provided that demand for palladium and platinum remains high.

The International Precious Metals Institute sponsored a seminar on PGM in October 1985 in Washington, DC. Experts on mining, economics, and uses of PGM presented papers at the meeting. European automotive emission legislation and automotive catalyst technology were discussed, among other topics.[15]

Progress on future commercial use of platinum in phosphoric acid fuel cells was discussed at a seminar in Italy in June. One researcher concluded that platinum supplies will be adequate to meet even the most optimistic projections of fuel cell usage, even though possible platinum requirements for fuel cells is very large.[16] The researcher cited, as an example of research and development progress, United Technologies Corp.'s completion of a 4.5-megawatt powerplant in Japan in 1982 that had produced electricity continuously since 1983. That success had encouraged United Technologies to develop an 11-megawatt plant, and Westinghouse to build a 7.5-megawatt plant, both of which were to be located in the United States. In addition, the Ministry of International Trade and Industry in Japan was underwriting the development of a number of 1-megawatt plants to be operational by 1986.

Using a supported ruthenium catalyst, scientists at the Stanford Research Institute succeeded for the first time in electrochemically producing appreciable amounts of methane from water and carbon dioxide. Synthetic methane produced in this way could eventually supplement natural gas as a fuel or chemical feedstock, but problems remain in determining the mechanisms at work in the process, and in removing the need to use ultrapure ruthenium.[17]

Cisplatin is a drug made from platinum that is used for treating some types of cancer. The Kitasato University in Tokyo announced preliminary evidence that administration of sodium selenite along with cisplatin reduces the toxic side effects of the drug on both the kidney and the intestine without compromising its antitumor activity.[18]

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[1] Physical scientist, Division of Nonferrous Metals.

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[7] Johnson Matthey P.L.C. Platinum—1985 Interim Review. 19 pp.

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[11] Sumitomo Corp. Precious Metals Market in Japan. 16th ed., Feb. 1986, 18 pp.

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[13] Mining Journal. Expansion at Western Plats. V. 304, No. 7807, Apr. 5, 1985, pp. 235, 237.

[14] U.S. Congress, Office of Technology Assessment. Strategic Materials: Technologies To Reduce U.S. Import Vulnerability. OTA-ITE-248, May 1985, 409 pp.

[15] International Precious Metals Institute. Proceedings From the Platinum Group Metals Seminar 1985. Washington, DC, Oct. 1985, 251 pp.

[16] Cameron, D. S. Catalysts for Fuel Cell Applications. Platinum Met. Rev., v. 29, No. 3, July 1985, pp. 107-112.

[17] Chemical and Engineering News. Carbon Dioxide Reduced to Methane Electrolytically. v. 63, No. 27, July 8, 1985, p. 29.

[18] ———. Selenite May Make Cisplatin a More Useful Drug. V. 63, No. 1, Jan. 7, 1985, p. 49.

# Potash

## By James P. Searls[1]

U.S. potash production and apparent consumption in terms of potassium oxide ($K_2O$) equivalent decreased significantly in 1985. Spring production again exceeded fall production. Sales by U.S. producers fell 23% for the year, and average prices decreased to a lesser extent. Yearend stocks increased slightly. The United States continued to be a net importer of potash; net import reliance as a percentage of apparent consumption was 76%. Canada provided an amount equal to 80% of the domestic apparent consumption. U.S. exports rose, however, with increased exports to India, Japan, and Mexico.

Three Carlsbad, NM, mines and plants were sold during the year. Two Carlsbad mines and plants were closed temporarily at yearend. A Utah plant remained closed throughout the year to repair flood damage.

**Domestic Data Coverage.**—Domestic production data for potash are developed by the Bureau of Mines from a voluntary semiannual survey of U.S. operations. Of the 10 operations to which a survey request was sent, all responded, representing 100% of the total production shown in table 1. The temporarily closed plants reported beginning stocks, sales, and ending stocks.

**Table 1.—Salient potash[1] statistics**

(Thousand metric tons and thousand dollars unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production | 4,153 | 3,366 | 2,770 | 3,039 | 2,569 |
| $K_2O$ equivalent | 2,156 | 1,784 | 1,429 | 1,564 | 1,296 |
| Sales by producers | 3,670 | 3,387 | 2,950 | 3,184 | 2,505 |
| $K_2O$ equivalent | 1,908 | 1,784 | 1,513 | 1,639 | 1,266 |
| Value[2] | $328,900 | $265,600 | $220,800 | $241,800 | $178,400 |
| Average value per ton of product dollars | $89.62 | $78.42 | $74.85 | $75.95 | $71.22 |
| Average value per ton of $K_2O$ equivalent do | $172.40 | $148.87 | $145.97 | $147.55 | $140.89 |
| Exports[3] | 887 | 952 | 564 | 836 | 973 |
| $K_2O$ equivalent | 491 | 519 | 300 | 446 | 518 |
| Value[4] | $107,950 | $93,200 | $55,760 | $85,660 | NA |
| Imports for consumption[5] [3] | 7,908 | 6,338 | 7,322 | 7,948 | 7,571 |
| $K_2O$ equivalent | 4,796 | 3,858 | 4,440 | 4,829 | 4,598 |
| Customs value | $750,400 | $575,400 | $600,600 | $658,100 | $499,100 |
| Apparent consumption[6] | 10,686 | 8,778 | 9,708 | 10,296 | 9,103 |
| $K_2O$ equivalent | 6,218 | 5,123 | 5,653 | 6,022 | 5,346 |
| Yearend producers' stocks, $K_2O$ equivalent | 520 | 520 | [7]391 | [8]312 | [9]336 |
| World: Production, marketable $K_2O$ equivalent | [r]27,075 | [r]24,509 | 27,418 | [p]29,348 | [e]28,618 |

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1] Includes muriate and sulfate of potash, potassium magnesium sulfate, glaserite, and some parent salts. Excludes other chemical compounds containing potassium.

[2] F.o.b. mine.

[3] Excludes potassium chemicals and mixed fertilizers.

[4] F.a.s. U.S. port.

[5] Includes nitrate of potash.

[6] Measured by production plus imports minus exports plus industry and Government stock changes.

[7] Inventory adjustment of minus 46,000 tons.

[8] Inventory adjustment of minus 4,000 tons.

[9] Inventory adjustment of minus 6,000 tons.

## DOMESTIC PRODUCTION

Domestic $K_2O$ production fell 17% in 1985. Of the total production for the year, 75% was standard, coarse, and granular muriate of potash, also known as potassium chloride, and 8% was sulfate of potash, also known as potassium sulfate. The remaining production comprised manure salts, glaserite, soluble and chemical grades of muriate of potash, and sulfate of potash-magnesia, also known as potassium magnesium sulfate. The terms "standard," "coarse," and "granular" refer to particle sizes of the finished product.

The New Mexico producers accounted for 85% of the total marketable salts production. New Mexico crude salt mine production was 11.3 million metric tons with an average $K_2O$ content of 13.3%. Five companies produced potash from underground, bedded sylvinite and langbeinite deposits east of Carlsbad. At the beginning of the year, the producers were AMAX Chemical Corp. of AMAX Inc.; the Duval Corp. of Pennzoil Co.; International Minerals & Chemical Corp. (IMC); Kerr-McGee Chemical Corp. of Kerr-McGee Corp.; and Potash Co. of America (PCA) of Ideal Basic Industries Inc.

All of the Carlsbad producers operated at reduced levels during the year. AMAX Chemical's operation was closed indefinitely in November. The Duval operation was renamed Potash Producers Inc. early in the year, then sold and renamed Western Ag-Minerals Corp. The new owners of Western Ag-Minerals were Warburg, Pincus Capital Partners, 75%, a New York venture banking firm, and Rayrock Resources Ltd., 25%, a Toronto, Canada, mining firm. The Kerr-McGee Chemical Hobbs facility was sold to Vertac Chemical Corp. of Memphis, TN, and renamed New Mexico Potash Co. The new owner sold potash primarily to its potassium nitrate manufacturing plant in Vicksburg, TN, and to the oil drilling and chemical industries; only excess material was sold to the agricultural industry. PCA, which closed in December to reduce stocks of finished product, was sold at yearend and renamed Lundberg Industries Ltd.

Mississippi Chemical Corp., whose mine had been closed since January 1983, purchased the permanently closed National Potash Co. property and started salvage operations on the underground equipment and materiel.

Sylvinite ore was used for muriate of potash production, and langbeinite ore was used for sulfate of potash-magnesia production. IMC mined both ores and reacted fractions of each potash product to produce sulfate of potash.

Sulfate of potash was also manufactured at two plants in Texas. The PCA, subsequently Lundberg Industries, plant produced sulfate of potash from Hargreaves furnaces using muriate of potash and sulfur dioxide; that production was included in Bureau of Mines statistics because PCA had mined the potash feed in New Mexico. The Permian Chemical Corp. plant reported production of about 15,000 tons[3] from its Mannheim furnaces using muriate of potash and sulfuric acid, but its production was not included in Bureau of Mines statistics because Permian was not a mining firm. Both firms sold byproduct hydrochloric acid to the Texas petroleum industry for oil well acidification.

In Utah, Texasgulf Chemicals Co. of Texasgulf Inc., which is owned by Elf Aquitaine Inc. of the Paris-based Société Nationale Elf Aquitaine, produced muriate of potash from underground, bedded sylvinite deposits by solution mining and solar evaporation. Kaiser Chemicals of Kaiser Aluminum & Chemical Corp. produced muriate of potash from near-surface brines at the west end of the Bonneville Salt Flats by solar evaporation and flotation. Great Salt Lake Minerals & Chemicals Corp., a subsidiary of Gulf Resources & Chemical Corp., remained closed throughout the year while repairing flood damage. A new sulfate of potash manufacturer, Climax Chemical Co., produced about 8,000 tons, but its production was not included in Bureau of Mines statistics because Climax Chemical was not a mining firm. Climax Chemical had been a sodium sulfate producer that converted to potassium sulfate production.

In California, Kerr-McGee Chemical continued to produce both muriate and sulfate of potash along with other products from underground brines at Searles Lake.

## Table 2.—Production, sales, and inventory of U.S. produced potash, by type and grade

(Thousand metric tons and thousand dollars)

| Type and grade | Production | | | | Sold or used | | | | | | Stocks, end of 6-month period | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gross weight | | $K_2O$ equivalent | | Gross weight | | $K_2O$ equivalent | | Value[1] | | Gross weight | | $K_2O$ equivalent | |
| | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 |
| January-June: | | | | | | | | | | | | | | |
| Muriate of potash, 60% $K_2O$ minimum: | | | | | | | | | | | | | | |
| Standard | 368 | 434 | 226 | 266 | 467 | 431 | 286 | 264 | 30,500 | 27,000 | 133 | 143 | 82 | 83 |
| Coarse | [r]150 | 95 | 92 | 58 | 196 | 96 | 121 | 59 | 13,900 | 6,100 | 46 | 60 | 28 | 37 |
| Granular | 543 | 369 | 331 | 223 | 529 | 417 | 322 | 252 | 37,200 | 25,600 | 149 | 111 | 91 | 68 |
| Chemical | 31 | 21 | 20 | 14 | 32 | 20 | 20 | 18 | W | W | ([2]) | 5 | ([2]) | 8 |
| Potassium sulfate | 100 | 99 | 51 | 51 | 145 | 98 | 74 | 50 | 27,600 | 18,500 | 49 | 61 | 25 | 32 |
| Other potassium salts[3] | 381 | 342 | 94 | 92 | 426 | 393 | 104 | 104 | W | W | 228 | 200 | 51 | 46 |
| Total[4] | 1,573 | 1,360 | 818 | 704 | 1,794 | 1,455 | 927 | 742 | 189,800 | 106,000 | 607 | 580 | 278 | 274 |
| July-December: | | | | | | | | | | | | | | |
| Muriate of potash, 60% $K_2O$ minimum: | | | | | | | | | | | | | | |
| Standard | 418 | 396 | 256 | 242 | 406 | 307 | 249 | 188 | 26,400 | 18,400 | 140 | 232 | 85 | 141 |
| Coarse | 157 | 58 | 97 | 35 | 142 | 67 | 88 | 41 | 9,100 | 3,600 | 61 | 48 | 38 | 30 |
| Granular | 385 | 254 | 233 | 154 | 373 | 264 | 227 | 160 | 23,600 | 12,600 | 160 | 95 | 97 | 58 |
| Chemical | 19 | 21 | 12 | 14 | 15 | 17 | 9 | 11 | W | W | 4 | 10 | 3 | 6 |
| Potassium sulfate | 112 | 108 | 57 | 55 | 101 | 103 | 52 | 53 | 19,600 | 18,000 | 60 | 66 | 31 | 34 |
| Other potassium salts[3] | 375 | 372 | 95 | 92 | 352 | 292 | 88 | 71 | W | W | 251 | 279 | 58 | 67 |
| Total[4] | 1,466 | 1,209 | 751 | 592 | 1,389 | 1,050 | 712 | 524 | 102,500 | 72,400 | 677 | 730 | 312 | 336 |
| Grand total[4] | 3,039 | 2,569 | 1,564 | 1,296 | 3,184 | 2,505 | 1,639 | 1,266 | 241,800 | 178,400 | XX | XX | XX | XX |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.

[1] F.o.b. mine.

[2] Less than 1/2 unit.

[3] Includes soluble muriate, glaserite, manure salts, and potassium magnesium sulfate.

[4] Data may not add to totals shown because of independent rounding.

### Table 3.—Production and sales of potash in New Mexico

(Thousand metric tons and thousand dollars)

| Period | Crude salts[1] (mine production) |  | Marketable potassium salts |  |  |  |  |
|---|---|---|---|---|---|---|---|
|  |  |  | Production |  | Sold or used |  |  |
|  | Gross weight | $K_2O$ equivalent | Gross weight | $K_2O$ equivalent | Gross weight | $K_2O$ equivalent | Value[2] |
| 1984: |  |  |  |  |  |  |  |
| January-June | 7,209 | 973 | 1,484 | 733 | 1,575 | 801 | $118,000 |
| July-December | [r]6,903 | [r]919 | 1,302 | 655 | 1,225 | 618 | 86,100 |
| Total[3] | [r]14,112 | [r]1,892 | 2,785 | 1,388 | 2,799 | 1,418 | 204,100 |
| 1985: |  |  |  |  |  |  |  |
| January-June | 6,160 | 827 | 1,221 | 623 | 1,322 | 666 | 93,900 |
| July-December | 5,152 | 683 | 1,014 | 479 | 927 | 454 | 62,100 |
| Total | 11,312 | 1,510 | 2,235 | 1,102 | 2,249 | 1,120 | 156,000 |

[r] Revised.

[1] Sylvinite and langbeinite.

[2] F.o.b. mine.

[3] Data may not add to totals shown because of independent rounding.

### Table 4.—Salient U.S. sulfate of potash[1] statistics

(Thousand metric tons of $K_2O$ equivalent and thousand dollars)

|  | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Production | 200 | 166 | 168 | 109 | 106 |
| Sales by producers | 178 | 176 | 156 | 126 | 103 |
| Value[2] | $61,993 | $61,934 | $55,453 | $47,197 | $36,465 |
| Exports[3] | 40 | 71 | 44 | 34 | 46 |
| Value[4] | $16,095 | $27,648 | $16,390 | $13,940 | NA |
| Imports[3] | 18 | 6 | 29 | 29 | 25 |
| Value[5] | $7,380 | $2,409 | $12,300 | $12,600 | $10,400 |
| Apparent consumption[6] | 156 | 111 | 141 | 121 | 82 |
| Yearend producers' stocks | 46 | 36 | 44 | 31 | 34 |

NA Not available.

[1] Excludes potassium magnesium sulfate.

[2] F.o.b. mine.

[3] Bureau of the Census.

[4] F.a.s. U.S. port.

[5] C.i.f. to U.S. port.

[6] Measured by production plus imports minus exports plus industry and Government stock changes.

## CONSUMPTION AND USES

Apparent domestic consumption of all forms of potash decreased from that of 1984. Downward pressure on demand for fertilizers in the United States continued to come from the decline in demand for U.S.-produced crops and the stockpile remaining from previous record crop-years. Crop buyers from foreign countries found U.S. crops to be relatively expensive because of the combination of the high value of the U.S. dollar and the level at which the U.S. Government supported crop prices relative to the world market price. Even U.S. farmers who could earn profits without price supports lost money-borrowing power for fertilizer purchases because of the strongly declining value of their cropland, which was used as collateral for bank loans. Corn Belt land values had declined an average of 44% between 1981 and 1985. Farmers expected calendar year 1986 to be a poor year for exports, and because the Food Security Act of 1985 was not passed until December, they failed to make large fertilizer purchases in the fall, which usually accounted for 60% of the year's consumption.

According to the Potash & Phosphate Institute, the major consumers of agricultural potash from Canadian and U.S. potash producers, in decreasing order, were Illinois, Iowa, Indiana, Ohio, Minnesota, and Wisconsin. These six States consumed 54% of the total from Canadian and U.S. producers. However, domestic producers provided only 6% of Illinois' potash consumption, 2% of Iowa's consumption, 1% of Indiana's consumption, 1% of Ohio's consumption, 10% of Minnesota's consumption, and 4% of Wisconsin's consumption. Potash from other countries was consumed in these States, but quantities are unknown. The major agricultural consumers of domestically produced potash, in decreasing order, were Texas, Missouri, California, Illinois, Minnesota, and Florida. These six States accounted for 56% of the total. The major agricultural consumers of domestically produced sulfates of potash, in decreasing order, were Florida, Georgia, California, Texas, Kentucky, and North Carolina. These six States accounted for 59% of the total.

**Table 5.—Sales of North American potash, by State of destination**

(Metric tons of $K_2O$ equivalent)

| State | Agricultural potash | | Nonagricultural potash | |
|---|---|---|---|---|
| | 1984 | 1985 | 1984 | 1985 |
| Alabama | 78,041 | 65,558 | 61,940 | 63,576 |
| Alaska | 257 | 217 | -- | -- |
| Arizona | 438 | 390 | 22 | 112 |
| Arkansas | 44,179 | 54,803 | 140 | 620 |
| California | 62,054 | 51,059 | 10,992 | 8,848 |
| Colorado | 13,051 | 8,323 | 6,083 | 7,044 |
| Connecticut | 4,282 | 5,625 | 52 | 119 |
| Delaware | 27,694 | 16,394 | 35,755 | 33,500 |
| Florida | 148,230 | 114,560 | 865 | 3,891 |
| Georgia | 162,351 | 155,822 | 957 | 1,990 |
| Hawaii | 16,056 | 13,561 | -- | -- |
| Idaho | 19,008 | 24,223 | -- | 51 |
| Illinois | 717,548 | 663,632 | 32,942 | 22,347 |
| Indiana | 362,757 | 399,639 | 2,352 | 357 |
| Iowa | 493,110 | 400,412 | 1,226 | 454 |
| Kansas | 33,653 | 30,199 | 2,549 | 1,984 |
| Kentucky | 149,555 | 132,288 | 364 | 341 |
| Louisiana | 49,783 | 54,181 | 1,775 | 1,444 |
| Maine | 7,160 | 7,711 | 114 | 416 |
| Maryland | 24,088 | 27,875 | 509 | 175 |
| Massachusetts | 5,015 | 3,382 | 534 | 586 |
| Michigan | 204,048 | 185,586 | 1,702 | 1,501 |
| Minnesota | 360,667 | 350,467 | 36 | 335 |
| Mississippi | 49,804 | 32,010 | 3,165 | 28,382 |
| Missouri | 247,720 | 232,460 | 3,458 | 3,281 |
| Montana | 13,029 | 10,185 | 135 | 71 |
| Nebraska | 39,180 | 32,252 | 113 | 462 |
| Nevada | 12 | -- | 249 | 59 |
| New Hampshire | 553 | 767 | -- | 24 |
| New Jersey | 6,819 | 7,907 | 11,463 | 13,250 |
| New Mexico | 6,831 | 11,373 | 29,685 | 34,673 |
| New York | 78,520 | 82,410 | 976 | 1,261 |
| North Carolina | 103,421 | 117,822 | 46 | 158 |
| North Dakota | 22,099 | 20,092 | 104 | 384 |
| Ohio | 396,761 | 399,025 | 60,423 | 58,922 |
| Oklahoma | 41,778 | 22,729 | 7,796 | 9,105 |
| Oregon | 26,154 | 24,612 | 1,485 | 1,437 |
| Pennsylvania | 48,601 | 63,018 | 4,036 | 2,427 |
| Rhode Island | 2,258 | 2,207 | 110 | 92 |
| South Carolina | 65,909 | 66,496 | 117 | 167 |
| South Dakota | 11,769 | 10,894 | 7 | -- |
| Tennessee | 131,052 | 140,373 | 423 | 591 |
| Texas | 140,996 | 135,722 | 47,317 | 42,998 |
| Utah | 4,254 | 14,491 | 13,563 | 11,880 |
| Vermont | 3,712 | 5,029 | -- | 14 |
| Virginia | 65,384 | 63,037 | 331 | 200 |
| Washington | 40,241 | 38,735 | 2,905 | 2,546 |
| West Virginia | 4,150 | 4,911 | 1,280 | 601 |
| Wisconsin | 280,336 | 292,508 | 201 | 487 |
| Wyoming | 1,854 | 2,188 | 824 | 643 |
| **Total** | 4,816,222 | 4,599,160 | 351,121 | 363,806 |

Source: Potash & Phosphate Institute.

Table 6.—Sales of North American muriate of potash to U.S. customers, by grade

(Thousand metric tons of $K_2O$ equivalent)

| Grade | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|
| Agricultural: | | | | |
| Standard | 563 | 399 | 446 | 346 |
| Coarse | 1,750 | 2,402 | 2,219 | 2,065 |
| Granular | 1,237 | 1,533 | 1,511 | 1,666 |
| Soluble | 357 | 451 | 471 | 392 |
| Total | 3,907 | 4,785 | 4,647 | 4,469 |
| Nonagricultural: | | | | |
| Soluble | 106 | 114 | 120 | 138 |
| Other | 210 | 195 | 227 | 227 |
| Total | 316 | 309 | 347 | 365 |
| Grand total | 4,223 | 5,094 | 4,994 | 4,834 |

Source: Potash & Phosphate Institute.

According to the Potash & Phosphate Institute, which reported sales of U.S. and Canadian producers by grade and State, domestic sales of muriate of potash for agricultural uses changed as follows: Standard grade fell 22%, coarse grade fell about 7%, granular grade rose about 10%, and sulfate of potash and sulfate of potash-magnesia combined fell 23%. The percentage breakdown of total sales by grade and type was 45% coarse muriate, 36% granular muriate, 9% soluble muriate, 7% standard muriate, and 3% sulfates of both types and all sizes. Potash sales of the domestic producers as a percentage of total domestic sales represented 5% of the coarse muriate, 17% of the granular muriate, 3% of the soluble muriate, 27% of the standard muriate, and 100% of both types and all sizes of sulfates.

The Potash & Phosphate Institute also reported a slight increase in potash sold for nonagricultural uses. Of this, standard muriate was 60%, soluble muriate was 38%, and sulfates of both types and all sizes was 2%. Nonagricultural uses of potash were primarily for producing caustic potash and chlorine. Caustic potash, or potassium hydroxide, was used as a caustic chemical and as the major precursor to other potassium chemicals. A minor industrial use of muriate of potash was as an addition to oil well drilling muds. Diamond Shamrock Corp. announced an expansion of caustic potash capacity at its plant in Mobile, AL. Monsanto Co. announced the cessation of caustic potash manufacturing at its Sauget, IL, chlor-alkali plant. The demise of Allied Chemical Corp.'s synthetic soda ash plant at Syracuse, NY, left only Diamond Shamrock's Muscle Shoals, AL, plant producing potassium carbonate.

## STOCKS

Yearend producers' stocks of potash increased slightly over that of 1984. Yearend stocks were 26% of annual production or 13.5 weeks of production. Several producers reported inventory adjustments between December 1984 and January 1985, and between June and July 1985. The effective total stock adjustment between December 1984 and December 1985 was minus 6,000 tons.

## TRANSPORTATION

Ocean freight rates from Hamburg, Federal Republic of Germany, to India and from Vancouver, Canada, to India fell slowly throughout the year. Both fell from about $30 per ton to the lower or middle $20's. Published U.S. rail tariffs were unchanged in the southern half of the country, whereas some railroads in the northern half of the country reduced their rates to compete with truck backhauls. Unpublished, i.e., Staggers Act, contracts and contract rates declined. The Canadian railroads raised their published rates to the United States by 7% in November. The collapse in October of an underwater section of a lock on the Welland Canal between Lake Erie and Lake Ontario delayed grain movements from the Central United States and Canada to the Atlantic Basin for nearly 1 month, but the potash trade was unaffected. The Tennessee-Tombigbee Waterway opened on June 1 between the Tombigbee River, which passes to the sea at Mobile, AL, and the Tennessee River in northeastern Mississippi; the effect on potash trade has been negligible.

About 900,000 tons of Canadian muriate of potash passed through Thunder Bay, Ontario, Canada, for lake freightage to U.S. Great Lakes ports. About 900,000 tons of Canadian muriate of potash was shipped to Minneapolis or St. Louis for transfer to barges.

## PRICES

The domestic potash market was oversupplied, with ensuing low prices. Potash prices near yearend, f.o.b. plant for domestic producers and at the U.S. border for foreign producers, appeared to be below costs of production for some domestic producers. The average price, f.o.b. mine, of U.S. potash sales of all types and grades decreased slightly to $140.89 per ton. The average price was $142.71 in the first half of the year and $138.31 in the second half. The average annual price for the three grades of muriate fell to $96 per ton. Standard-grade muriate of potash averaged $100 per ton, coarse-grade averaged $96 per ton, and granular-grade, which had the greatest price decrease, averaged $93 per ton. The average annual price for sulfate of potash declined to $353 per ton.

**Table 7.—Prices[1] of U.S. potash, by type and grade**

(Dollars per metric ton of $K_2O$ equivalent)

| Type and grade | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | January-June | July-December | January-June | July-December | January-June | July-December |
| Muriate, 60% $K_2O$ minimum: | | | | | | |
| Standard | 93.56 | 98.52 | 106.44 | 106.20 | 101.99 | 97.37 |
| Coarse | 108.13 | 104.73 | 115.23 | 103.33 | 102.42 | 87.35 |
| Granular | 104.46 | 99.44 | 115.68 | 103.97 | 101.30 | 78.85 |
| All muriate[2] | 100.10 | 99.75 | 111.98 | 104.86 | 101.73 | 88.71 |
| Sulfate, 50% $K_2O$ minimum | 353.19 | 359.03 | 374.22 | 377.21 | 367.24 | 339.98 |

[1] Average prices, f.o.b. mine, based on sales.

[2] Excluding soluble and chemical muriates.

## FOREIGN TRADE

U.S. potash exports rose 16%, by ton product. The major destinations in Latin America, which received 53% of the exports, by ton product, were Brazil, Mexico, Colombia, the Dominican Republic, Costa Rica, and Chile. These countries represented 90% of the exports to Latin America. Exports to Brazil, Colombia, and the Dominican Republic declined slightly while exports to Chile rose nearly 70%; to Mexico, nearly 60%; and to Costa Rica, nearly 15%. Exports to Japan rose by 67% and to New Zealand, by nearly 37%. Exports to Canada fell nearly 18%, and exports to India rose from zero.

A 5% decrease in total U.S. imports of potash was represented primarily by decreases in muriate from the U.S.S.R. and the German Democratic Republic. Imports of muriate from Canada were essentially unchanged from that of 1984 and amounted to 94% of all muriate imports and 93%, by $K_2O$ equivalent, of all potash imports. Israel was the second largest source of imports, with 6% of muriate of potash imports and 6%, by $K_2O$ equivalent, of total potash imports.

The remaining dumping petitions before the International Trade Commission (ITC) were against the German Democratic Republic and the U.S.S.R. These investigations were completed in early 1985 with determinations in both cases that potash had not been sold for less than fair value; the preliminary findings had called for greater than 100% antidumping duties on imports from both countries. The countervailing duty petitions against these two countries had been dropped in 1984 by the International Trade Administration of the U.S. Department of Commerce because of the difficulty of the analysis. The petitioners joined an appeal in the U.S. Court of International Trade concerning a similar decision. The Court Opinion and Order reversed and remanded the Commerce determinations that "...subsidies... could not be found in countries with nonmarket economies." An appeal by Commerce was in progress at yearend.

## Table 8.—U.S. exports of potash

| | Approximate average $K_2O$ content (percent) | Quantity (metric tons) | | Value (thousands) |
|---|---|---|---|---|
| | | Product | $K_2O$ equivalent | |
| **1984[1]** | | | | |
| Potassium chloride, all grades | 61 | 621,820 | 379,300 | [2]$57,200 |
| Potassium sulfate | 51 | 67,320 | 34,340 | [2]13,940 |
| Potassium magnesium sulfate | 22 | 147,160 | 32,380 | [2]14,550 |
| Total | XX | 836,300 | 446,020 | [2] [3]85,660 |
| **1985[4]** | | | | |
| Potassium chloride, all grades | 61 | 699,770 | 426,860 | NA |
| Potassium sulfate | 51 | 91,000 | 46,410 | NA |
| Potassium magnesium sulfate | 22 | 182,290 | 40,100 | NA |
| Total | XX | 973,060 | 513,370 | NA |

NA Not available XX Not applicable.

[1] Source: Bureau of the Census, as adjusted by the Bureau of Mines.

[2] F.a.s. U.S. port.

[3] Data do not add to total shown because of independent rounding.

[4] Source: Bureau of the Census. Census ceased reporting value of shipments as of July 1985.

## Table 9.—U.S. exports of potash, by country

| Country | Metric tons of product | | | | | | Total value[3] (thousands) | |
|---|---|---|---|---|---|---|---|---|
| | Potassium chloride | | Potassium sulfates, all grades[1] | | Total[2] | | | |
| | 1984[4] | 1985[5] | 1984[4] | 1985[5] | 1984[4] | 1985[5] | 1984[4] | 1985[5] |
| Argentina | 2,000 | 3,150 | -- | 1,490 | 2,000 | 4,640 | $200 | NA |
| Australia | 11,520 | 11,810 | 9,050 | 10,000 | 20,570 | 21,810 | 2,940 | NA |
| Bahamas | -- | -- | 1,790 | 2,650 | 1,790 | 2,650 | 380 | NA |
| Belgium | -- | -- | 3,000 | 43 | 3,000 | 43 | 270 | NA |
| Belize | -- | 1,350 | -- | -- | -- | 1,350 | -- | NA |
| Brazil | 289,930 | 272,070 | 4,000 | 5,500 | 293,930 | 277,570 | 28,200 | NA |
| Canada | 1,590 | 3,430 | 73,440 | 58,430 | 75,030 | 61,860 | 9,500 | NA |
| Chile | -- | -- | 12,350 | 20,910 | 12,350 | 20,910 | 2,560 | NA |
| Colombia | 43,480 | 48,860 | 16,130 | 8,840 | 59,610 | 57,700 | 5,940 | NA |
| Costa Rica | 6,450 | 8,520 | 14,690 | 15,620 | 21,140 | 24,140 | 2,340 | NA |
| Dominican Republic | 26,770 | 20,840 | 1,740 | 5,710 | 28,500 | 26,550 | 2,860 | NA |
| Ecuador | 14,980 | 12,100 | 5,110 | 3,350 | 20,090 | 15,450 | 1,810 | NA |
| French West Indies | -- | 5,250 | 3,150 | 4,580 | 3,150 | 9,830 | 340 | NA |
| Guatemala | 3,160 | 14 | 420 | 3,040 | 3,580 | 3,050 | 400 | NA |
| Haiti | 600 | 74 | 10 | 27 | 611 | 100 | 67 | NA |
| Honduras | 620 | -- | 90 | 240 | 710 | 240 | 67 | NA |
| India | -- | 43,780 | -- | -- | -- | 43,780 | -- | NA |
| Italy | -- | 110 | 7 | 250 | 7 | 360 | 2 | NA |
| Jamaica | -- | 120 | -- | -- | -- | 120 | -- | NA |
| Japan | 74,910 | 76,650 | 10,220 | 65,150 | 85,130 | 141,800 | 6,830 | NA |
| Korea, Republic of | -- | -- | 46 | 6,950 | 46 | 6,950 | 5 | NA |
| Leeward and Windward Islands | 1,550 | -- | 64 | -- | 1,610 | -- | 170 | NA |
| Malaysia | -- | 14,250 | 23,800 | 12,100 | 23,800 | 26,350 | 1,900 | NA |
| Mexico | 42,190 | 77,820 | 26,310 | 30,100 | 68,500 | 107,920 | 8,530 | NA |
| New Zealand | 59,090 | 81,820 | 370 | -- | 59,460 | 81,280 | 5,260 | NA |
| Panama | 4,250 | 1,450 | 150 | 290 | 4,400 | 1,740 | 440 | NA |
| Peru | 19,160 | 14,420 | 1,210 | 1,260 | 20,380 | 15,680 | 1,840 | NA |
| Philippines | 35 | -- | 2,130 | 11,600 | 2,160 | 11,600 | 420 | NA |
| Salvador | -- | -- | -- | 550 | -- | 550 | -- | NA |
| Saudi Arabia | 7 | -- | 180 | 60 | 180 | 60 | 20 | NA |
| Sweden | -- | 500 | 640 | -- | 640 | 500 | 150 | NA |
| Taiwan | 400 | -- | -- | 490 | 400 | 490 | 30 | NA |
| Thailand | -- | -- | 4,000 | -- | 4,000 | -- | 360 | NA |
| Uruguay | -- | 1,270 | -- | -- | -- | 1,270 | -- | NA |
| Venezuela | 19,040 | 130 | 34 | -- | 19,080 | 130 | 1,760 | NA |
| Zambia | -- | -- | -- | 3,280 | -- | 3,280 | -- | NA |
| Other | 101 | 520 | 350 | 780 | 460 | 1,300 | 54 | NA |
| Total[2] | 621,820 | 699,770 | 214,480 | 273,290 | 836,300 | 973,060 | 85,660 | NA |

NA Not available.

[1] Includes potassium magnesium sulfate.

[2] Data may not add to totals shown because of independent rounding.

[3] F.a.s. U.S. port.

[4] Source: Bureau of the Census, as adjusted by the Bureau of Mines.

[5] Source: Bureau of the Census. Census ceased reporting value of shipments as of July 1985.

### Table 10.—U.S. imports for consumption of potash, by country

| Country | Metric tons of product | | | | | | | | | | Total value (thousands) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Potassium chloride | | Potassium sulfate | | Potassium nitrate | | Potassium sodium nitrate | | Total[1] | | Customs | | C.i.f. | |
| | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 |
| Belgium-Luxembourg | -- | 18 | 27,600 | -- | -- | -- | -- | -- | 27,600 | 18 | $5,500 | $11 | $5,900 | $11 |
| Canada | 7,188,400 | 7,005,200 | -- | -- | -- | 58 | -- | -- | 7,188,400 | 7,005,300 | 578,000 | 438,500 | 607,300 | 471,200 |
| Chile | -- | -- | -- | -- | -- | -- | 22,000 | 33,600 | 22,000 | 33,600 | 2,900 | 4,300 | 3,200 | 4,900 |
| China | -- | -- | -- | -- | 1 | -- | -- | -- | 1 | -- | (2) | -- | (2) | -- |
| France | 14 | -- | -- | -- | -- | -- | -- | -- | 14 | -- | 20 | -- | 24 | -- |
| German Democratic Republic | 100,900 | 24,200 | -- | -- | -- | -- | -- | -- | 100,900 | 24,200 | 7,900 | 1,700 | 9,700 | 2,100 |
| Germany, Federal Republic of | 5,500 | 4,400 | 29,000 | 49,800 | -- | -- | -- | -- | 34,500 | 54,200 | 7,100 | 10,100 | 7,800 | 11,000 |
| Israel | 412,800 | 420,400 | -- | -- | 20,500 | 30,400 | -- | -- | 433,300 | 450,800 | 45,800 | 43,700 | 50,900 | 49,800 |
| Japan | -- | -- | -- | -- | -- | 2 | 380 | 200 | 380 | 200 | 100 | 100 | 140 | 100 |
| Netherlands | 4,100 | 2,000 | 200 | -- | 1 | -- | -- | -- | 4,300 | 2,000 | 540 | 300 | 650 | 300 |
| Spain | 10,500 | -- | -- | -- | -- | -- | -- | -- | 10,500 | -- | 900 | -- | 1,000 | -- |
| U.S.S.R | 125,200 | -- | -- | -- | -- | -- | -- | -- | 125,200 | -- | 9,000 | -- | 10,300 | -- |
| United Kingdom | 650 | 600 | -- | -- | -- | -- | -- | -- | 650 | 600 | 300 | 400 | 400 | 400 |
| Total[1] | 7,848,100 | 7,456,800 | 56,800 | 49,800 | 20,500 | 30,500 | 22,300 | 33,800 | 7,947,700 | 7,570,900 | 658,100 | 499,100 | 697,400 | 539,900 |

[1] Data may not add to totals shown because of independent rounding.
[2] Less than 1/2 unit.

Source: Bureau of the Census, as adjusted by the Bureau of Mines.

Table 11.—U.S. imports for consumption of potash

| | Approximate average $K_2O$ content (percent) | Quantity (metric tons) | | Value (thousands) | |
|---|---|---|---|---|---|
| | | Product | $K_2O$ equivalent[e] | Customs | C.i.f. |
| 1984 | | | | | |
| Potassium chloride | 61 | 7,848,100 | 4,787,300 | $637,200 | $674,500 |
| Potassium sulfate | 50 | 56,800 | 29,000 | 11,700 | 12,600 |
| Potassium nitrate | 45 | 20,500 | 9,200 | 6,300 | 6,900 |
| Potassium sodium nitrate mixtures | 14 | 22,300 | 3,100 | 3,000 | 3,300 |
| Total[1] | XX | 7,947,700 | 4,828,600 | 658,100 | 697,400 |
| 1985 | | | | | |
| Potassium chloride | 61 | 7,456,800 | 4,548,700 | 476,000 | 514,600 |
| Potassium sulfate | 50 | 49,800 | 25,400 | 9,600 | 10,400 |
| Potassium nitrate | 45 | 30,500 | 13,700 | 9,100 | 9,900 |
| Potassium sodium nitrate mixtures | 14 | 33,800 | 4,700 | 4,400 | 5,000 |
| Total | XX | 7,570,900 | 4,592,500 | 499,100 | 539,900 |

[e] Estimated. XX Not applicable.
[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census, as adjusted by the Bureau of Mines.

## WORLD REVIEW

World production remained about the same as that in 1984 as Canadian potash producers limited production in an effort to maintain reasonable stock levels. World prices, as exemplified by the price of standard muriate of potash, f.o.b. Vancouver, Canada, reported by British Sulphur Corp., were in the middle $80's during the first half of 1985 and fell to the middle $70's by yearend. Potash was generally in oversupply at prices less than many producers' total costs.

**Argentina.**—An Argentinian firm, Cía. Minera Tea, and the U.S. subsidiary, Texasgulf, of the French firm Elf Aquitaine were exploring a reportedly large potash resource in Mendoza Province, which is on the western border of Argentina.

**Bolivia.**—The Government formed a new company, Complejo Industrial de los Recursos Evaporíticos del Salar de Uyuni, to develop the Salar de Uyuni. Proposals for a multiproduct plant included a 200,000-ton-per-year muriate of potash plant.

**Brazil.**—The new potash mine at Taquari-Vassouras was reported to have opened during the spring. In December 1983, the Government had estimated Brazil's total potash reserves to be 188 million tons.

**Canada.**—In the fall of 1984, during mining operations at the PCS Rocanville Mine, a connection with the overlying Dawson Bay water-bearing strata was encountered that caused some flooding of a gallery. The leak was stopped in the spring of 1985, by casting a large concrete plug in the gallery. Rocanville was closed for nearly 3 months. The Denison-Potacan Potash Co. mine and mill started production during the year. This muriate of potash plant had an 800,000-ton-per-year capacity. According to the Potash & Phosphate Institute, Denmark, France, Ireland, and Switzerland imported 124,000 tons of potash from Canada. Denmark had been importing potash from North America for many years; France was a partial owner of Denison-Potacan Potash. The PCS plan for a sulfate potash production plant on Quill Lake awaited a final decision. Quill Lake, east of Saskatoon in the Province of Saskatchewan, was considered to be a source of sulfate ions for the "glaserite" process.

The Central Canada Potash plant of Noranda Inc. was closed for about 3 months. The Cominco Ltd. plant at Vanscoy was closed for more than 2 months. The International Minerals & Chemical Corp. (Canada) Ltd. plants were closed for about 1.5 months. The PCA plant at Patience Lake was closed for more than 1 month. Three other PCS mines were closed for more than 3 months.

The Canadian subsidiary of PCA was sold

to Rio Algom Ltd., the Canadian subsidiary of Rio Tinto Zinc Corp. PLC of the United Kingdom. The sale included the Saskatchewan and New Brunswick mines and mills and the St. John, New Brunswick, loading dock and dockside warehouse. Rio Algom planned to invest nearly $22 million[3] into the Sussex, New Brunswick mine and mill to remove bottlenecks to full production.

**Table 12.—Salient Canadian potash statistics**

(Thousand metric tons of $K_2O$ equivalent)

| | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|
| Production[1] | 5,208 | 5,928 | 7,749 | 6,637 |
| Domestic sales by domestic producers[1] | 273 | 385 | 436 | 434 |
| Exports: | | | | |
| United States[1] | 3,202 | 3,965 | 3,892 | 4,163 |
| Overseas[1] | 1,576 | 2,026 | 2,544 | 1,928 |
| Imports for consumption[2] | 13 | 17 | 20 | 14 |
| Domestic consumption[3] | 286 | 402 | 456 | 448 |
| Yearend producers' stocks[1] | 1,486 | 862 | 1,543 | 1,766 |

[1] Data supplied by the Potash & Phosphate Institute.

[2] From Bureau of the Census export data. Muriate and nitrate of potash were landed on the Canadian east coast from European and Middle Eastern sources.

[3] Domestic sales by domestic producers plus imports.

**Chile.**—Sociedad Química y Minera de Chile announced plans for potassium nitrate production from facilities at Coya Sur in the Atacama Desert.

**Denmark.**—Superfos A/S annouced plans for a sulfate of potash manufacturing plant using gypsum and purchased muriate of potash.

**German Democratic Republic.**—The new port facilities at Rostock, to import urea and export potash, were completed. The potash storage facility was 35,000 tons of product with an annual flowthrough capacity of 400,000 tons. The vessel size limit was estimated to be 35,000 deadweight tons.

**Israel.**—The old flotation plant at the Dead Sea Works Ltd. (DSW) was closed from April through yearend to maintain reasonable potash stock levels. The parent company, Israel Chemicals Ltd., decided to reduce its 5-year, $1 billion investment plans by one-half. The planned investment in potash was cut to $125 million from $150 million, which was to have increased the plant capacity from 1.3 to 1.8 million tons. Declining oil prices have reduced the foreseeable profits from the Mediterranean Sea to Dead Sea electricity generation proposal, and the project has been abandoned. This project was expected to destructively change the Dead Sea's chemical composition and thereby alter the chemistry of the solar evaporation ponds for both the DSW and the Arab Potash Co. in Jordan. Construction of the 18-kilometer conveyor belt from Sdom to the Israel Railways terminal at Tsefa was started. The belt was designed to transport 800 tons per hour of potash from 400 meters below sea level to 400 meters above sea level.

**Jordan.**—The Arab Potash plant produced muriate of potash at more than one-third of the design capacity of 1.2 million tons in 1984 and one-half of capacity in 1985. The goal for 1985 production had been more than two-thirds of capacity. Near yearend, the firm asked for bids to modify the plant.

**Mexico.**—A potash recovery plant was reported to be under construction at the Cerro Prieto geothermal field.[4] Design capacity was 200,000 tons per year by solar evaporation and fractional crystallization from a feed of 2 cubic meters per second of brine from three powerplants.

**Spain.**—The Potasas de Navarra S.A. Mine south of Pamplona, owned by the Instituto Nacional de Industria (INI), was closed and reopened as the Potasas de Subiza Mine, owned 50% by INI and 50% by the government of the Province of Navarra. The rate of production was reduced from 325,000 tons to about 130,000 tons per year to extend the life of the mine. The work force dropped from about 2,000 to 600 employees. A new mine in Cataluña was being considered by either INI or Unión Explosivos Río Tinto S.A., the owner of Potasas de Llobregat and of Cardona.

**Thailand.**—The Sakon Nakon concession was offered for bid after AMAX Exploration Inc. failed to sign for the exploration rights.

**U.S.S.R.**—The potash resource that had been reported to be 70 billion tons along the Baykal-Amur Railway was named the Nepskoye deposit and reported to be 300 kilometers east of Ust-Kut in the Irkutsk Oblast on the Lena River. The Soligorsk No. 4 plant was reportedly experiencing continuing production difficulties. The plant had been placed into operation in 1979-80.

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[1] Physical scientist, Division of Industrial Minerals.

[2] All tonnages reported in metric tons, $K_2O$ equivalent, unless otherwise specified.

[3] Where necessary, values have been converted from Canadian dollars (CAN$) to U.S. dollars at a rate of CAN$1.3655=US$1.00, the average exchange rate for 1985.

[4] Espinosa, H. A. Geothermal, An Alternate Energy Source for Power Generation. Geotherm. Resour. Counc. Bull., Feb. 1985, pp. 9-12.

### Table 13.—Marketable potash: World production, by country[1]

(Thousand metric tons of $K_2O$ equivalent)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Canada (sales)[2] | 6,549 | 5,309 | 6,938 | 7,527 | 6,600 |
| Chile[3] | 21 | 21 | 21 | 18 | 19 |
| China[4] | 20 | 26 | 29 | 40 | 40 |
| France | 1,831 | 1,704 | 1,536 | 1,739 | 1,750 |
| German Democratic Republic | 3,460 | 3,434 | 3,431 | 3,465 | 3,475 |
| Germany, Federal Republic of | 2,591 | 2,056 | 2,419 | 2,644 | 2,580 |
| Israel | 839 | 1,004 | [e]1,000 | [e]1,100 | 1,100 |
| Italy | [r]142 | 146 | 184 | 178 | [5]205 |
| Jordan | -- | 9 | 172 | 295 | 550 |
| Spain | 732 | 692 | 657 | [e]677 | 660 |
| U.S.S.R | 8,449 | 8,079 | 9,294 | 9,776 | 10,000 |
| United Kingdom | 285 | [r]245 | 308 | 325 | 343 |
| United States | 2,156 | 1,784 | 1,429 | 1,564 | [5]1,296 |
| Total | [r]27,075 | [r]24,509 | 27,418 | 29,348 | 28,618 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Table includes data available through Apr. 29, 1986.

[2] Official Government figures. Potash & Phosphate Institute production data are given in table 12.

[3] Data represent officially reported output of potassium nitrate product (gross weight basis) converted assuming 14% $K_2O$ equivalent.

[4] Chinese data on production of potassic fertilizers are in terms of nutrient content; small additional quantities may be produced and used by the nonfertilizer chemical industry.

[5] Reported figure.

# Pumice and Pumicite

## By A. C. Meisinger[1]

Production of pumice and pumicite by 21 domestic producers in 1985 was 508,000 short tons valued at $4.6 million compared with 502,000 tons valued at $4.9 million in 1984. U.S. apparent consumption declined 6% to 749,000 tons, primarily because of a 17% decrease in imported pumice. Greece continued to be the major source of pumice imports with 98%. Estimated world production declined slightly to 12.1 million tons.

**Domestic Data Coverage.**—Domestic production data for pumice and pumicite are developed by the Bureau of Mines from one voluntary survey of U.S. operations. Of the 22 operations to which a survey request was sent, 18, or 82%, responded, representing 97% of total production data shown in table 1. Production for the four nonrespondents was estimated using reported prior year production levels adjusted by trends in employment and other guidelines.

**Table 1.—Salient pumice and pumicite statistics**

(Thousand short tons and thousand dollars unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: Sold and used by producers: | | | | | |
| Pumice and pumicite | 499 | 416 | 449 | 502 | 508 |
| Value (f.o.b. mine and/or mill) | $4,311 | $3,750 | $4,486 | $4,929 | $4,553 |
| Average value per ton | $8.64 | $9.01 | $9.99 | $9.82 | $8.96 |
| Exports[e] | 1 | 1 | 1 | 1 | 1 |
| Imports for consumption | 92 | 121 | 184 | 293 | 242 |
| Apparent consumption[1] | 590 | 536 | 632 | 794 | 749 |
| World: Production, pumice and related volcanic materials | [r]13,694 | [r]13,446 | 11,966 | [p]12,662 | [e]12,110 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Production plus imports, minus exports, plus adjustments for Government and industry stock changes.

## DOMESTIC PRODUCTION

Production of pumice and pumicite by domestic producers increased slightly to 508,000 tons, but decreased 8% in value to $4.6 million compared with 1984 output. Twenty-two mines and/or plants were operated by 21 companies in 8 States, with California, Idaho, New Mexico, and Oregon accounting for 96% of U.S. production.

Principal domestic producers were American Pumice Products Inc., Littlelake, CA; Tionesta Aggregates Co., Tulelake, CA; Amcor Inc., Idaho Falls, ID; Hess Pumice Products, Malad City, ID; Producers Pumice Inc., Boise, ID; Copar Pumice Co. Inc., Santa Fe, NM; General Pumice Co., Santa Fe, NM; Utility Block Co., Albuquerque, NM; Cascade Pumice Co., Bend, OR; and Central Oregon Pumice Co., Bend, OR. Together, these 10 companies accounted for 92% of the tonnage and 68% of the value of total

U.S. production of pumice and pumicite.

Hess Pumice Products announced the relocation of the company's milling operations and construction of a new mill in the Malad City Industrial Park during the year. Construction was expected to be completed in early 1986 and will be financed by industrial revenue bonds. The company's pumice mine is about twenty miles northwest of Malad City, ID.

**Table 2.—Pumice and pumicite sold and used by producers in the United States, by State**

(Thousand short tons and thousand dollars)

| State | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value |
| Arizona | 2 | 21 | W | 2 |
| California | 80 | 1,600 | 78 | 1,491 |
| New Mexico | 132 | 1,269 | 152 | 1,114 |
| Other[1] | 288 | 2,039 | 279 | 1,947 |
| Total[2] | 502 | 4,929 | 508 | 4,553 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes Hawaii, Idaho, Kansas, Oklahoma, Oregon, and data indicated by symbol W.

[2] Data may not add to totals shown because of independent rounding.

## CONSUMPTION AND USES

U.S. apparent consumption decreased 6% to 749,000 tons, owing, in large part, to a 17% decline in pumice imports compared with that of 1984. Principal uses of domestically produced pumice and pumicite increased 12% for abrasives and 20% for landscaping, but declined slightly for both concrete admixture and aggregate and decorative building block. Other uses of pumice increased 110%, primarily owing to increased use in road construction and maintenance during the year.

**Table 3.—Pumice and pumicite sold and used by producers in the United States, by use**

(Thousand short tons and thousand dollars)

| Use | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value |
| Abrasives (includes cleaning and scouring compounds) | 25 | 810 | 28 | 497 |
| Concrete admixture and aggregate | 169 | 876 | 158 | 818 |
| Decorative building block | 272 | 2,801 | 260 | 2,400 |
| Landscaping | 15 | 129 | 18 | 133 |
| Other[1] | 21 | 313 | 44 | 706 |
| Total | 502 | 4,929 | 508 | 4,553 |

[1] Includes heat-or-cold insulating medium, pesticide carriers, road construction material, roofing granules, and miscellaneous uses.

## PRICES

The average value, f.o.b. mine or mill, for domestic pumice and pumicite sold and used was $8.96 per ton, a 9% decrease from that of 1984, and the second straight year of decline.

Prices quoted in Chemical Marketing Reporter for domestic grades of pumice bagged in 1-ton lots were, at yearend, $270 per ton for fine and $300 per ton for medium, coarse, and 2-extra coarse. Yearend quoted prices on imported (Italian) pumice, f.o.b. east coast, bagged in 1-ton lots, were $280 per ton for fine, $350 per ton for medium, and $300 per ton for coarse.

The average declared customs value of pumice imported from Greece for use in concrete masonry products decreased from $6.82 to $6.47 per ton.

## FOREIGN TRADE

Pumice imported for consumption declined 17% to 242,000 tons. Greece was the principal source with a total of 237,600 tons, of which 237,535 tons was used to produce concrete masonry products.

**Table 4.—U.S. imports for consumption of pumice, by class and country**

| Country | Crude or unmanufactured | | Wholly or partly manufactured | | For use in the manufacture of concrete masonry products | | Manufactured, n.s.p.f. |
|---|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Value (thousands) |
| 1984: | | | | | | | |
| Greece | 5,167 | $75 | -- | -- | 275,756 | $1,880 | -- |
| Iceland | 8,228 | 153 | -- | -- | -- | -- | -- |
| Italy | 3,297 | 156 | 172 | $36 | -- | -- | $23 |
| Mexico | -- | -- | -- | -- | 72 | 2 | 1 |
| Other[1] | 11 | 18 | 20 | 12 | 3 | 3 | 124 |
| Total | 16,703 | 402 | 192 | 48 | 275,831 | 1,885 | 148 |
| 1985: | | | | | | | |
| Greece | 24 | 10 | 41 | 15 | 237,535 | 1,537 | 30 |
| Iceland | 498 | 92 | -- | -- | -- | -- | -- |
| India | -- | -- | -- | -- | 2,176 | 2 | -- |
| Italy | 120 | 42 | 294 | 79 | 1,051 | 7 | 44 |
| Mexico | 90 | 32 | -- | -- | -- | -- | -- |
| Other[2] | 49 | 22 | 22 | 9 | 1 | 1 | 144 |
| Total | 781 | 198 | 357 | 103 | 240,763 | 1,547 | 218 |

[1] Includes Austria, Canada, China, Denmark, France, the Federal Republic of Germany, Hong Kong, Japan, Nigeria, Spain, Switzerland, Taiwan, and the United Kingdom.

[2] Includes Austria, Canada, Denmark, Ecuador, France, the Federal Republic of Germany, Japan, Spain, Switzerland, Taiwan, and the United Kingdom.

Source: Bureau of the Census.

## WORLD REVIEW

World production of pumice and related volcanic materials declined 4% to an estimated 12.1 million tons. The combined output of Greece and Italy accounted for 65% of the world's total production. Of the remaining 35%, France, Spain, the United States, and Yugoslavia accounted for 63%.

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[1] Industry economist, Division of Industrial Minerals.

## Table 5.—Pumice and related volcanic materials: World production, by country[1]

(Thousand short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina[3] | 56 | 59 | 76 | 60 | 62 |
| Austria: Trass | 9 | 12 | 3 | 11 | 7 |
| Cameroon: Pozzolan | 58 | 89 | NA | NA | NA |
| Cape Verde Islands: Pozzolan[e] | 11 | 11 | 11 | 11 | 11 |
| Chile: Pozzolan | 306 | 190 | 192 | 190 | 188 |
| Costa Rica[e] | 1 | 2 | 2 | 2 | 2 |
| Dominica: Pumice and volcanic ash[e] | 120 | 120 | 120 | 120 | 120 |
| France: Pozzolan and lapilli | 518 | 790 | 669 | [r] [e]550 | 610 |
| Germany, Federal Republic of: | | | | | |
| Pumice (marketable) | [r]882 | [r]441 | 441 | 717 | 660 |
| Pozzolan[e] | 220 | 220 | NA | NA | NA |
| Greece: | | | | | |
| Pumice | [r]802 | 707 | 552 | 691 | 695 |
| Pozzolan | [r]1,312 | [r]1,297 | 1,004 | 1,001 | 1,005 |
| Guadeloupe: Pozzolan[e] | 265 | 265 | 265 | 265 | 265 |
| Guatemala: | | | | | |
| Pumice[e] | 17 | 13 | [4]17 | [r]15 | 15 |
| Volcanic ash | 6 | [e]4 | (5) | (5) | (5) |
| Iceland | 37 | [r]21 | 50 | [r] [e]60 | 65 |
| Italy:[e] | | | | | |
| Pumice and pumiceous lapilli | [4]671 | 825 | 770 | 720 | 660 |
| Pozzolan | [4]6,073 | 6,100 | 5,500 | 6,100 | 5,500 |
| Martinique: Pumice[e] | [4]172 | 170 | 165 | 165 | 165 |
| New Zealand | 37 | 55 | 19 | 17 | 22 |
| Spain[6] | 1,034 | 1,070 | 1,105 | 915 | 990 |
| United States (sold and used by producers) | 499 | 416 | 449 | 502 | [4]508 |
| Yugoslavia: Volcanic tuff | 588 | 569 | 556 | [r] [e]550 | 560 |
| Total | [r]13,694 | [r]13,446 | 11,966 | 12,662 | 12,110 |

[e] Estimated. [p] Preliminary. [r] Revised. NA Not available.

[1] Table includes data available through May 20, 1986.

[2] Pumice and related volcanic materials are also produced in a number of other countries, including (but not limited to) Ethiopia, Iran, Japan, Mexico, Turkey, and the U.S.S.R., but output is not reported quantitatively, and available information is inadequate for the formulation of reliable estimates of output levels.

[3] Unspecified volcanic materials produced mainly for use in construction products.

[4] Reported figure.

[5] Less than 1/2 unit.

[6] Includes Canary Islands.

# Rare-Earth Minerals and Metals

### By James B. Hedrick[1]

Domestic production of rare earths in 1985 dropped to its lowest level in 9 years as a result of decreased demand in certain market sectors. Producers operated at about one-half of their rated production capacity. Foreign sources of rare earths gained a larger share of the U.S. market, while domestic exports remained essentially unchanged from 1984 levels. Molycorp Inc., a wholly owned subsidiary of Unocal Corp., and Associated Minerals (USA) Ltd. Inc., a subsidiary of the Australian-owned company Renison Goldfields Consolidated Ltd., were the only domestic mine producers of rare-earth minerals. Mine production by Molycorp accounted for the significant decline in domestic rare-earth production in 1985, while Associated Minerals operated at a record-high level. Molycorp, Rhône-Poulenc Inc., W. R. Grace & Co.'s Davison Chemical Div., and NUCOR Corp.'s Research Chemicals Div. were the principal processors of rare earths in the United States. Major end uses were in petroleum cracking catalysts, metallurgical applications, glass and ceramics, and permanent magnets.

**Domestic Data Coverage.**—Domestic mine production data for rare earths are developed by the Bureau of Mines from a voluntary survey of U.S. operations, the "Rare Earths and Thorium" survey. Both mines to which a survey request was sent responded, representing 100% of total production. Production data are withheld to avoid disclosing company proprietary data.

**Table 1.—Salient U.S. rare earth statistics**

(Metric tons of rare-earth oxides (REO) unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Production of rare-earth concentrates[1] | 17,082 | 17,501 | 17,083 | 25,311 | 13,428 |
| Exports:[e] | | | | | |
| Ore and concentrate | 5,056 | 2,565 | 2,684 | 4,304 | 4,419 |
| Ferrocerium and pyrophoric alloys | 9 | 22 | 59 | 27 | 23 |
| Imports for consumption:[e] | | | | | |
| Monazite | 4,108 | 3,962 | 2,215 | 3,114 | 3,132 |
| Metals, alloys, oxides, compounds | 1,631 | 1,695 | 1,857 | 2,926 | 1,124 |
| Shipments from Government stockpile | 802 | 364 | -- | -- | -- |
| Stocks, producers and processors, yearend | W | W | W | W | W |
| Consumption, apparent[e] | 20,000 | 17,100 | 19,600 | 21,400 | 12,100 |
| Prices, yearend, dollars per kilogram: | | | | | |
| Bastnasite concentrate, REO basis | $2.14 | $2.31 | $2.14 | $2.14 | $2.14 |
| Monazite concentrate, REO basis | $0.83 | $0.75 | $0.71 | $0.64 | $1.09 |
| Mischmetal, metal basis | $12.35 | $12.35 | $12.35 | $12.35 | $12.35 |
| Employment, mine and mill[e] [2] | 275 | 303 | 266 | 321 | 330 |
| Net import reliance[e] [3] as a percent of apparent consumption | 14 | ([4]) | 12 | ([4]) | ([4]) |

[e] Estimated. W Withheld to avoid disclosing company proprietary data.

[1] Comprises only the rare earths derived from bastnasite, as reported in Unocal Corp. (previously Union Oil Co. of California) annual reports.

[2] Employment at a rare-earth mine in California and at minerals sands operations in Florida and Georgia. The latter mines produced monazite concentrate as a byproduct of mining ilmenite, rutile, and zircon, and employees were not assigned to specific commodities.

[3] Imports minus exports plus adjustments for Government and industry stock changes.

[4] Increase in industry stocks exceeded net imports.

## DOMESTIC PRODUCTION

According to Unocal's annual report, Molycorp's sales of rare earths declined in 1985, primarily as a result of decreased demand for rare-earth-containing fluid cracking catalysts used in leaded fuel production. New regulations by the Environmental Protection Agency, which sharply reduced the amount of lead that can be added to boost octane levels in gasoline, were cited as the cause of the reduced rare-earth demand. Sales of Molycorp's lower volume, higher value separated rare earths, especially those compounds used in the manufacture of phosphors and permanent magnets, were reportedly strong.

Unocal's Canadian subsidiary, Unocal Canada Ltd., formed a joint venture with two other Canadian companies, Denison Mines Ltd., and a new company, SM Yttrium of Canada, which represents the interests of the Japanese companies Shin-Etsu Chemical Co. and Mitsui & Co., to recover yttrium and rare-earth concentrate as a byproduct of processing uranium leach solutions from Denison's Elliot Lake Mine. Molycorp planned to process the concentrate at its Louviers, CO, facilities to produce high-purity yttrium and rare-earth compounds. Molycorp's decision to obtain its own yttrium concentrate was believed to be the result of increasing costs and the uncertainty of adequate supplies of imported yttrium concentrate, produced mainly as a byproduct of processing tin in Malaysia. Yttrium's strong and growing demand as a phosphor and ceramic material was probably another consideration in the joint venture investment.

General Motors Corp. planned to produce neodymium-iron-boron permanent magnets using a General Motors-developed rapid solidification process at a new plant in Anderson, IN. The company was scheduled to initially produce the magnets for use in starter motors in selected late-1986-model year cars and further expand use and applications to its other vehicles in 1987.[2] General Motors expected to market 80% of its neodymium-iron-boron magnet production outside the company.

M&M Minerals Inc. will reportedly recover monazite and other heavy minerals from three streams in the vicinity of Concord, NC, beginning in 1986. The placer operation was to have a capacity of about 40,000 metric tons per year of ore containing about 18% heavy minerals, including 5% monazite.[3]

Associated Minerals installed a bucket wheel excavator on the floating dredge at its Green Cove Springs, FL, minerals sands operations. The equipment was expected to increase recovery and throughput of heavy minerals, including monazite, by dredging faster in the harder, shallower layers of the Green Cove Springs ore body.[4]

## CONSUMPTION AND USES

Domestic rare-earth processors consumed an estimated 12,700 tons of equivalent rare-earth oxides (REO) in various forms in 1985, 49% less than was consumed in 1984. Consumption of bastnasite and monazite decreased 51% and 21%, respectively, from that of 1984. The decreased consumption was attributed principally to lower demand in the rare-earth petroleum catalyst market.

Shipments of rare-earth products from domestic processors of ore, concentrates, and intermediate concentrates amounted to 14,000 tons of equivalent REO, a decrease of 32% from the revised 1984 shipments of 20,500 tons.

Consumption of mixed rare-earth compounds (REO basis) was essentially unchanged from the 1984 level, while consumption of purified compounds (REO basis) increased 6%. Higher consumption of purified compounds was the result of strong demand for samarium, neodymium, dysprosium, and certain other rare earths used in high-strength permanent magnets, for yttrium and europium oxides used in phosphors, and for yttrium oxide used in high-temperature ceramics and refractory applications.

The producers of mischmetal, rare-earth silicide, and other rare-earth alloys consumed 24% less rare earths in 1985 than in 1984, while shipments of these goods fell 38% during the same period. Shipments of high-purity rare-earth metals increased 4% during the year.

The approximate distribution of rare earths by end use, based on information supplied by primary processors and some consumers, was as follows: petroleum catalysts (including chemical processing catalysts), 46%; metallurgical uses (including iron and steel additives, alloys, and mischmetal), 32%; ceramics and glass (including polishing compounds and glass additives), 18%; and miscellaneous uses (including phosphors, electronics, permanent magnets, lighting, and research), 4%.

The glass industry's principal use of rare earths, mainly cerium concentrate or cerium oxide, was as polishing compounds for lenses, mirrors, cut crystal, television and cathode-ray tube faceplates, gem stones, and plate glass. Purified rare-earth compounds were also used as additives to glass used in containers, television and cathode-ray tube faceplates, radiation shielding windows, opthalmic lenses, lasers, incandescent and fluorescent lights, and optical, photochromic, filter, and photographic lenses. The rare-earth additives acted as colorants, color correctors, and decolorizers, as stabilizers against discoloration from ultraviolet light and against browning caused by high-energy radiation, as dopants in laser glass, as modifiers to increase refractive indices and decrease dispersion, and as absorbers of ultraviolet and visible light.

Phosphors containing rare earths were used in color television tubes, radar screens, avionic and data displays, X-ray intensifying screens, low- and high-pressure mercury vapor lights, electronic thermometers, and trichromatic fluorescent lamps.

The ceramics industry used purified rare earths in pigments, heating elements, dielectric and conductive ceramics, thermal and/or flash protective devices, stereoviewing systems, data printers, image storage devices, and as principal constituents and stabilizers in high-temperature refractories such as yttria-stabilized zirconia and in glasses and paints.

Purified rare-earth compounds also had applications in petroleum cracking catalysts, noncracking catalysts, oxygen-sensing electrolytes, computer bubble domain memories, substrates for bubble domain memories, dyes and softeners for textiles, electronic components, nuclear fuel reprocessing, microwave applications, incandescent gas mantles, gas lasers, fiber optics, carbon arc lighting, fertilizers, and synthetic gem stones.

Rare-earth permanent magnets were used in electric motors, alternators, generators, line printers, computer disk-drive actuators, proton linear accelerators, synchronous torque couples, eddy current brakes, microwave focusing, magnetrons, klystrons, medical and dental applications, including nuclear magnetic resonance imaging, traveling wave tubes, metallic separators, aerospace applications including electric actuators for ailerons and rudders, and in speakers, headphones, microphones, and tape drives.

Metallurgical applications of rare earths included alloys and additives in high-strength low-alloy steels, gray and ductile iron, stainless and carbon steels, high-temperature and corrosion-resistant metals, hydrogen storage alloys used in heat exchangers and fuel cells, lighter flints, armaments, permanent magnets, neutron convertor foils, special lead fuses, target materials for sealed-tube neutron generators, and high-voltage transmission cable.

## STOCKS

U.S. Government stocks of rare earths in the National Defense Stockpile (NDS), all classified as excess to goal, remained at 457 tons throughout 1985. Rare-earth stocks held in the NDS were contained in sodium sulfate and were inventoried on a contained-REO basis. Authority to dispose of these excess rare earths was suspended effective October 1, 1984, by section 902 of the Department of Defense Authorization Act, 1985. Stocks of yttrium oxide held in non-NDS Government inventories remained at 108 kilograms, all declared excess and authorized for disposal.

Industry stocks of rare earths held by 23 producing, processing, and consuming companies increased 6%. Bastnasite concentrate stocks held by the principal producer and four other processors remained essentially unchanged from the yearend 1984 level. Yearend stocks of monazite concentrates increased 92%, while stocks of other concentrates, including yttrium, increased 10%.

Stocks of mixed rare-earth compounds decreased 9%, while stocks of purified compounds, mostly separated rare-earth oxides, increased 5%. Yearend stocks of mischmetal, rare-earth silicide, and other alloys containing rare earths were down 8%, while inventories of high-purity rare-earth metals were 27% higher.

## PRICES

The price of Australian monazite (minimum 55% rare-earth oxide including thoria, f.o.b./f.i.d.),[6] as quoted in Metal Bulletin (London), in Australian dollars (A$), increased substantially from the range A$410 to A$450 per ton at yearend 1984 to A$850 to A$900 per ton by yearend 1985. Changes in the foreign exchange rate in 1985, resulting from the continued economic strength of the U.S. dollar against the Australian dollar, caused the corresponding U.S. price to rise less sharply from the range US$340 to US$365 in 1984[6] to US$580 to US$614 in 1985.[7]

The yearend price quoted in Industrial Minerals (London) for yttrium concentrate (60% $Y_2O_3$, f.o.b. Malaysia) was $46 per kilogram. Domestic prices quoted for yttrium concentrate during 1985, developed by the Bureau of Mines from various sources, ranged from $51 to $63 per kilogram of contained yttrium oxide.

Prices quoted by Molycorp for unleached, leached, and calcined bastnasite, containing 60%, 70%, and 85% REO, were $0.92, $0.97, and $1.17 per pound of contained REO, respectively, at yearend 1985, unchanged since 1983.

The price of cerium concentrate quoted by American Metal Market was $1.40 per pound of contained cerium oxide at yearend 1985; the yearend 1984 price was $1.32. The price of lanthanum concentrate also increased in 1985 to $1.40 per pound of REO contained, up 8 cents per pound from that of yearend 1984.

The mischmetal (99.8%, lots over 100 pounds, f.o.b. shipping point) price, quoted in American Metal Market, declined from the yearend 1984 price of $5.60 per pound to the range $5.00 to $5.60 per pound at yearend 1985.

Molycorp quoted prices for lanthanide (rare-earth) and yttrium oxides, net 30 days, f.o.b. Louviers, CO, Mountain Pass, CA, or York, PA, effective January 2, 1985, as follows:

| Product (oxide) | Percent[1] purity | Quantity (pounds) | Price per pound |
|---|---|---|---|
| Cerium | 99.0 | 200 | $8.00 |
| Europium | 99.99 | 25 | 725.00 |
| Gadolinium | 99.99 | 55 | 60.00 |
| Lanthanum | 99.99 | 300 | 7.00 |
| Neodymium | 96.0 | 300 | 4.00 |
| Do | 99.9 | 50 | 40.00 |
| Praseodymium | 96.0 | 300 | 16.80 |
| Samarium | 96.0 | 55 | 30.00 |
| Terbium | 99.9 | 55 | 375.00 |
| Yttrium | 99.99 | 50 | 50.00 |

[1] Purity expressed as percent of total REO.

Molycorp also quoted prices for lanthanide (rare-earth) compounds, net 30 days, f.o.b. York, PA, or Louviers, CO, effective January 2, 1985, as follows:

| Product (compound) | Percent purity | Quantity (pounds) | Price[1] per pound |
|---|---|---|---|
| Cerium carbonate | 99.0 | 150 | $4.00 |
| Cerium fluoride | Tech grade | 250 | 2.50 |
| Cerium nitrate | 95.0 | 250 | 2.15 |
| Lanthanide chloride | 46.0 | 525 | .84 |
| Lanthanum carbonate | 99.9 | 300 | 4.60 |
| Lanthanum chloride | 46.0 | 525 | .95 |
| Lanthanum-lanthanide carbonate | 60.0 | 200 | 2.45 |
| Lanthanum-lanthanide nitrate | 39.0 | 250 | 1.75 |
| Neodymium carbonate | 96.0 | 300 | 2.65 |

[1] Priced on a contained REO basis.

Rhône-Poulenc quoted rare-earth prices, per kilogram, net 30 days, f.o.b. New Brunswick, NJ, or duty paid at point of entry, effective January 1, 1985, as follows:

| Product[1] (oxide) | Percent purity | Quantity (kilograms) | Price per kilogram |
|---|---|---|---|
| Cerium | 99.5 | 20 | $20.35 |
| Erbium | 96.0 | 50 | 190.00 |
| Europium | 99.99 | 40 | 1,725.00 |
| Gadolinium | 99.99 | 50 | 136.50 |
| Lanthanum | 99.99 | 25 | 17.25 |
| Praseodymium | 96.0 | 20 | 38.85 |
| Samarium | 96.0 | 25 | 70.00 |
| Terbium | 99.9 | 20 | 875.00 |
| Yttrium | 99.99 | 50 | 115.50 |

[1] Dysprosium, holmium, lutetium, thulium, and ytterbium oxide prices on request from Rhône-Poulenc Inc.

Rhône-Poulenc also quoted prices for rare earths produced at its Freeport, TX, plant, net 30 days, f.o.b. Freeport, TX, effective January 1, 1985, as follows:

| Product (compound) | Percent[1] purity | Quantity (kilograms) | Price[2] per kilogram |
|---|---|---|---|
| Cerium carbonate | 95.0 | 20 | $8.60 |
| Cerium hydroxide | 95.0 | 20 | 11.25 |
| Cerium nitrate | 95.0 | 200 | 11.05 |
| Cerium oxide | 99.5 | 20 | 17.75 |
| Lanthanum carbonate | 99.5 | 20 | 12.60 |
| Lanthanum-neodymium carbonate | 98.0 | 20 | 7.20 |
| Lanthanum nitrate | 99.5 | 200 | 11.90 |
| Lanthanum oxide | 99.5 | 20 | 13.25 |
| Neodymium carbonate | 95.0 | 20 | 7.75 |
| Neodymium nitrate | 95.0 | 200 | 8.40 |
| Neodymium oxide | 95.0 | 20 | 9.25 |

[1] Purity expressed as percent of total REO.
[2] Priced on a contained REO basis.

Nominal prices for various rare-earth products were quoted by Research Chemicals, net 30 days, f.o.b. Phoenix, AZ, effective October 1, 1982, and throughout 1983, 1984, and 1985, as follows:

| Element | Oxide[1] price per kilogram | Metal[2] price per kilogram |
|---|---|---|
| Cerium | $20 | $125 |
| Dysprosium | 110 | 300 |
| Erbium | 200 | 650 |
| Europium | 1,900 | 7,500 |
| Gadolinium | 140 | 485 |
| Holmium | 650 | 1,600 |
| Lanthanum | 19 | 125 |
| Lutetium | 5,200 | 14,200 |
| Neodymium | 80 | 260 |
| Praseodymium | 130 | 310 |
| Samarium | 130 | 330 |
| Terbium | 1,200 | 2,800 |
| Thulium | 3,400 | 8,000 |
| Ytterbium | 225 | 875 |
| Yttrium | 118 | 510 |

[1] Minimum 99.9% purity, 1- to 20-kilogram quantities.
[2] Ingot form, 1 to 5 kilograms, from 99.9%-grade oxides.

## FOREIGN TRADE

Exports of rare-earth concentrates, produced primarily from bastnasite, originated mainly from Molycorp's Mountain Pass Mine in California. Exports of rare-earth metal ores, including bastnasite and a variety of mixed and individual rare-earth concentrates, but excluding monazite, decreased slightly from 8.0 million kilograms in 1984 to 7.7 million kilograms in 1985. They were valued at $14.8 million in 1985. Major destinations were Japan, 62%; Austria, 9%; and the United Kingdom, 7%.

Exports of ferrocerium and other pyrophoric alloys containing rare earths totaled 25,840 kilograms, 16% less than those of 1984. Major destinations for these exports were Japan, 59%; Yugoslavia, 19%; and Canada, 14%.

Exports of thorium ore, including monazite, increased significantly for the second consecutive year. France was the destination of all of the reported total of 743,103 kilograms, valued at $415,024, approximately $558.50 per ton.

The import tariff for yttrium-bearing ores, materials, and compounds, which excludes high-purity yttrium oxide, was suspended in 1984 for nations having most-favored-nation status. The revised import classification for yttrium ores and concentrates was TSUS (Tariff Schedule of the United States) No. 907.51, which was scheduled to remain in effect until July 1, 1988.

## Table 2.—U.S. import duties on rare earths

| Item | TSUS No. | Most favored nation (MFN) |  | Non-MFN |
|---|---|---|---|---|
|  |  | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Ore and concentrate[1] | 601.12, 601.45 | Free | Free | Free. |
| Cerium chloride, oxide, compounds | 418.40, 418.42, 418.44 | 9.2% ad valorem. | 7.2% ad valorem. | 35% ad valorem. |
| Rare-earth oxides except cerium oxide | 423.0030 | 4% ad valorem. | 3.7% ad valorem. | 25% ad valorem. |
| Rare-earth metals (including scandium and yttrium). | 632.38 | do | do | Do. |
| Alloys wholly or almost wholly of rare-earth metals (mischmetal). | 632.78 | 38 cents per pound. | 32 cents per pound. | $2 per pound. |
| Other alloys wholly or almost wholly of rare-earth metals. | 632.79 | 27 cents per pound plus 3.3% ad valorem. | 20 cents per pound plus 2.4% ad valorem. | $2 per pound plus 25% ad valorem. |
| Ferrocerium and other pyrophoric alloys | 755.35 | 29 cents per pound plus 3.5% ad valorem. | 22 cents per pound plus 2.6% ad valorem. | Do. |
| Yttrium-bearing materials and compounds (includes yttrium concentrates). | 907.51 | Free | Free | 25% ad valorem or 30% ad valorem.[2] |

[1] Crude or concentrated by crushing, flotation, washing, or by other physical or mechanical processes that do not involve substantial chemical change.

[2] Tariff is 25% if previous import item classification was 423.00 or 423.96, part 2, schedule 4, or 30% if 603.70, part 1, schedule 6.

## Table 3.—U.S. imports for consumption of monazite, by country

| Country | 1981 |  | 1982 |  | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Australia | 7,469 | $3,158 | 6,600 | $2,830 | 3,726 | $1,395 | 5,610 | $2,156 | 5,694 | $1,984 |
| Malaysia | -- | -- | 603 | 240 | 302 | 122 | -- | -- | -- | -- |
| South Africa, Republic of | -- | -- | -- | -- | -- | -- | 51 | 46 | -- | -- |
| Total | 7,469 | 3,158 | 7,208 | 3,070 | 4,028 | 1,517 | 5,661 | 2,202 | 5,694 | 1,984 |
| REO content[e] | 4,108 | XX | 3,962 | XX | 2,215 | XX | 3,114 | XX | 3,132 | XX |

[e] Estimated. XX Not applicable.

Source: Bureau of the Census. REO content estimated by the Bureau of Mines.

## Table 4.—U.S. imports for consumption of rare earths, by country

| Country | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity (kilograms) | Value | Quantity (kilograms) | Value | Quantity (kilograms) | Value |
| Cerium chloride: |  |  |  |  |  |  |
| Malaysia | -- | -- | 701,092 | $754,588 | -- | -- |
| Netherlands | 227 | $5,136 | -- | -- | -- | -- |
| Total | 227 | 5,136 | 701,092 | 754,588 | -- | -- |
| Cerium compounds: |  |  |  |  |  |  |
| France | 3,500 | 13,505 | 1,000 | 4,778 | 1,770 | $8,981 |
| Germany, Federal Republic of | 25 | 9,433 | 42 | 10,373 | 206 | 34,469 |
| Japan | 800 | 1,038 | 207 | 9,226 | -- | -- |
| South Africa, Republic of | 2 | 791 | -- | -- | -- | -- |
| Switzerland | 2 | 670 | 1 | 266 | -- | -- |
| United Kingdom | -- | -- | 5 | 783 | 10 | 2,306 |
| Total | 4,329 | 25,437 | 1,255 | 25,426 | 1,986 | 45,756 |

### Table 4.—U.S. imports for consumption of rare earths, by country —Continued

| Country | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity (kilograms) | Value | Quantity (kilograms) | Value | Quantity (kilograms) | Value |
| **Cerium oxide:** |  |  |  |  |  |  |
| Austria | 68 | $674 | 68 | $738 | -- | -- |
| Belgium-Luxembourg | 18,120 | 6,504 | -- | -- | -- | -- |
| France | 6,239 | 78,136 | 3,790 | 53,891 | 5,327 | $81,670 |
| Germany, Federal Republic of | 2 | 381 | 12 | 1,457 | 94 | 2,283 |
| Japan | 835 | 7,692 | 3,357 | 30,522 | -- | -- |
| Switzerland | 3 | 335 | 6 | 1,207 | -- | -- |
| United Kingdom | 50 | 536 | 40 | 287 | 27 | 1,707 |
| Total | 25,317 | 94,258 | 7,273 | 88,102 | 5,448 | 85,660 |
| **Cerium salts: France** | 1,760 | 6,580 | -- | -- | -- | -- |
| **Rare-earth oxide excluding cerium oxide:** |  |  |  |  |  |  |
| Austria | -- | -- | 50 | 2,646 | -- | -- |
| Belgium-Luxembourg | 55 | 25,906 | 16,803 | 42,856 | 110 | 46,342 |
| Brazil | 54,999 | 575,850 | -- | -- | -- | -- |
| Canada | 100 | 128,611 | 83,815 | 23,264 | -- | -- |
| China | 19,575 | 450,033 | 4,058 | 263,084 | 3,830 | 348,923 |
| France | 206,345 | 9,393,632 | 271,555 | 13,880,011 | 170,556 | 11,132,432 |
| Germany, Federal Republic of | 702 | 191,953 | 1,078 | 284,165 | 811 | 266,218 |
| India | -- | -- | 199,998 | 192,500 | -- | -- |
| Italy | 22,640 | 10,466 | -- | -- | -- | -- |
| Japan | 10,983 | 585,262 | 14,311 | 1,034,997 | 7,814 | 872,788 |
| Korea, Republic of | -- | -- | 68 | 5,087 | -- | -- |
| Malaysia | 273,597 | 251,022 | 274,592 | 295,907 | 6,210 | 186,534 |
| Mexico | -- | -- | 50,499 | 2,222 | -- | -- |
| Netherlands | -- | -- | 54 | 23,459 | 513 | 36,372 |
| Norway | 7,128 | 778,743 | 6,168 | 659,184 | 5,996 | 655,382 |
| Switzerland | 5 | 4,790 | -- | -- | 318 | 111,800 |
| Taiwan | 500 | 31,184 | -- | -- | -- | -- |
| U.S.S.R | 12,657 | 1,237,136 | 11,984 | 747,572 | 6,506 | 691,201 |
| United Kingdom | 31 | 6,196 | 225 | 28,541 | 197 | 38,133 |
| Total | 609,317 | 13,670,784 | 935,258 | 17,485,495 | 202,861 | 14,386,115 |
| **Rare-earth alloys:**[1] |  |  |  |  |  |  |
| Austria | -- | -- | 52,463 | 444,685 | -- | -- |
| Brazil | 65,147 | 457,419 | 79,993 | 526,031 | 162,998 | 817,875 |
| France | -- | -- | -- | -- | 1,062 | 9,946 |
| Germany, Federal Republic of | 9,870 | 143,328 | 11,276 | 100,653 | 17,211 | 167,343 |
| United Kingdom | 237 | 41,038 | 5 | 485 | 5,057 | 35,535 |
| Total | 75,254 | 641,785 | 143,737 | 1,071,854 | 186,328 | 1,030,699 |
| **Rare-earth metals including scandium and yttrium:** |  |  |  |  |  |  |
| Austria | -- | -- | -- | -- | 100 | 2,968 |
| China | -- | -- | 1,573 | 59,526 | -- | -- |
| France | 50 | 1,805 | -- | -- | -- | -- |
| Japan | 81 | 12,679 | -- | -- | 1,000 | 76,099 |
| Malaysia | -- | -- | 40 | 644 | -- | -- |
| U.S.S.R | 300 | 70,500 | 700 | 164,735 | 2,061 | 183,044 |
| United Kingdom | 370 | 97,258 | 2,003 | 394,484 | 24 | 22,642 |
| Total | 801 | 182,242 | 4,316 | 619,389 | 3,185 | 284,753 |
| **Other rare-earth metals:** |  |  |  |  |  |  |
| China | -- | -- | 1,000 | 1,181 | -- | -- |
| France | -- | -- | 135 | 3,979 | 329 | 9,870 |
| Germany, Federal Republic of | 46 | 5,524 | 77 | 7,514 | 655 | 15,275 |
| Japan | 422 | 8,237 | -- | -- | -- | -- |
| United Kingdom | 5 | 359 | -- | -- | 209 | 9,225 |
| Total | 473 | 14,120 | 1,212 | 12,674 | 1,193 | 34,370 |
| **Ferrocerium and other pyrophoric alloys:** |  |  |  |  |  |  |
| Austria | 953 | 13,430 | 937 | 12,875 | 1,000 | 13,240 |
| Brazil | 28,839 | 396,715 | 47,388 | 685,088 | 45,349 | 632,014 |
| France | 54,321 | 576,549 | 72,470 | 695,395 | 66,771 | 641,505 |
| German Democratic Republic | -- | -- | 170 | 1,589 | -- | -- |
| Germany, Federal Republic of | -- | -- | 459 | 5,340 | -- | -- |
| Japan | 13,190 | 176,108 | 15,537 | 204,308 | 20 | 1,699 |
| Sweden | 6,694 | 7,816 | -- | -- | -- | -- |
| Taiwan | 91 | 410 | -- | -- | -- | -- |
| United Kingdom | 608 | 14,288 | 1,167 | 45,965 | 245 | 13,080 |
| Total | 104,696 | 1,185,316 | 138,128 | 1,650,560 | 113,385 | 1,301.538 |

[1] Essentially all mischmetal.

Source: Bureau of the Census.

## WORLD REVIEW

Bastnasite, the world's principal source of rare earths, was mined as a primary product in the United States and as a byproduct of iron ore mining in China. Significant quantities of rare earths were also recovered from monazite, primarily a byproduct of minerals sands mined for titanium and zirconium minerals or tin in Australia, Brazil, China, India, and Malaysia. Smaller quantities of rare earths, especially yttrium, were obtained from the yttrium-rich minerals sands byproduct xenotime. Xenotime was mined primarily in Malaysia as a byproduct of processing tin ore, but was also produced in Australia, China, and Thailand.

World rare-earth reserves were estimated by the Bureau of Mines at 45 million tons of contained REO, of which 19% is in market economy countries.[8] China, with 80%, had the largest share of world reserves.

**Australia.**—Renison Goldfields announced its bid to take over control of Allied Eneabba Ltd. Several offers by Renison Goldfields to gain control of Allied through stock purchases had occurred by yearend. The corporate takeover, if successful, would make Renison Goldfields the world's principal minerals sands producer.[9] Renison Goldfields reported in its annual report that all of its minerals sands mines operated at full capacity in 1985. After 52 years of minerals sands mining on the east coast of Australia, Renison Goldfields closed its operations on North Stradbroke Island, Queensland, after depleting its reserves. Legislation by the Australian Government, resulting from environmental concerns, prevented Renison Goldfields, and other companies from mining on Moreton Island, Queensland. Moreton Island is one of the few remaining east coast areas with minerals sands reserves. Renison Goldfields, at Eneabba, Western Australia, obtained a new transportable high-rate thickener and was to install a new plant circuit design to improve recoveries of minerals sands including monazite.

Allied, in a joint venture with Asahi Chemical Industry Co. Ltd. of Japan, was studying the feasibility of building a rare-earth separation plant at Geraldton, Western Australia, to process monazite. Monazite concentrates produced to date have been exported for further processing and separation, with Australian companies reportedly foregoing the added revenues to be gained through secondary refining.[10] Renison Goldfields' takeover bid was not expected to affect the proposed Allied-Asahi separation plant venture.

Consolidated Rutile Ltd. (CRL) reportedly began minerals sands production at the Gordon Lease property on the southern end of North Stradbroke Island, Queensland. The property was acquired by CRL from Associated Minerals Consolidated Ltd. (AMC), a wholly owned subsidiary of Renison Goldfields, in the first quarter of 1985. CRL also completed an agreement with AMC for the acquisition of all of AMC's holdings on the island.[11]

A new company, $TiO_2$ Corp. NL, owned by Griffiths Bros. Ltd. (80%) and Spunthill Pty. Ltd. (20%), announced plans to mine minerals sands deposits at Jurien Bay and Cooljarloo in Western Australia. These deposits were previously worked by Western Mining Corp. in the mid-1970's. Cooljarloo's reserves were given as 16 million tons of proven and 42 million tons of probable ore grading 3% to 5% heavy minerals, including monazite. Reserves at Jurien Bay were listed at 25 million tons of proven and 1 million tons of probable ore grading 6% to 7% heavy minerals including monazite. Monazite comprises about 0.2% of the mined sand at Cooljarloo and 0.7% at Jurien Bay. Total reserves were equivalent to 64,000 tons of REO at Cooljarloo and 100,000 tons of REO at Jurien Bay.[12] Production from Cooljarloo was planned for 1988. Monazite production capacities for Cooljarloo and Jurien Bay were estimated at 400 tons (220 tons of REO equivalent) and 1,200 tons (660 tons of REO equivalent) per year, respectively.[13]

A joint venture was formed by Strategic Minerals Corp. (SMC) and Rutile & Zircon Mines (Newcastle) Ltd. (RZM) to explore and develop SMC's heavy minerals sands deposits at Byfield, Queensland. Reportedly, RZM can earn an 80% equity in the project by either the expenditure of $2.05 million or by completing a final feasibility study leading to a decision to mine.[14]

**Bangladesh.**—Reportedly, Bangladesh will spend $7 million on a 5-year plan to extract heavy minerals, including monazite, from the Cox's Bazaar coastal area. The beach sands, located 100 kilometers southeast of Chittagong, along the coast and on nearby islands, contained resources estimated at 5 million tons of heavy minerals.[15]

**Brazil.**—Minerals sands production at Cumuruxatiba in Bahia State began in

1985. Monazite, along with ilmenite, rutile, and zircon were reportedly recovered at the mine. Concentrates produced at Cumuruxatiba reportedly were shipped to the São Paulo processing plant operated by the state-controlled Nuclebras de Monazita e Associados Ltda., where rare-earth compounds were produced.[16]

Official statistics for Brazil for 1985 were not available, but data for previous years were reported in Anuário Mineral Brasileiro 1985.[17] Production of various rare-earth compounds, in kilograms, was reported as follows:

| Year | Carbonate | Chloride | Oxide |
|---|---|---|---|
| 1980 | 5,750 | 2,071,456 | 11,716 |
| 1981 | 5,550 | 1,910,100 | 21,605 |
| 1982 | 11,500 | 1,882,700 | 54,100 |
| 1983 | 8,250 | 2,002,347 | 16,160 |
| 1984 | 4,860 | 1,815,200 | 82,850 |

Production of crude monazite ore from the State of Espírito Santo in 1984 was 530 tons, compared with 915 tons in 1983, and was 3,635 tons from the State of Rio de Janeiro, compared with 5,015 tons in 1983.

Measured reserves of monazite in Brazil were 13,705 tons for 1984. Estimated REO equivalent content based on these reserves was 7,500 tons. Monazite reserves were in the States of Espírito Santo, Paraná, and Rio de Janeiro.[18]

**Canada.**—Iron Ore Co. of Canada decided not to develop its Strange Lake yttrium-beryllium-zirconium deposit northeast of Schefferville, Quebec. The decision was reportedly based on an assessment of the current commodity market, in which a new rare-earth and yttrium recovery plant was planned in Canada, and companies in the United States were considering mine development and recovery of rare earths and yttrium from tailings.

Highwood Resources Ltd. continued feasibility studies at its specialty metals deposit at Thor Lake, 80 miles southeast of Yellowknife, Northwest Territories. The deposit contains rare earths, yttrium, and beryllium. A 490-meter decline driven into the high-grade beryllium T-zone reportedly intersected a high-grade bastnasite zone up to 6 meters thick. Proven reserves of 431,000 tons of ore grading 0.2% yttrium oxide were reported. Samples recovered from the exploration decline were to be tested, with the results forming the basis for a production decision.[19]

Denison Mines, SM Yttrium Canada (a joint venture of the Japanese companies Shin-Etsu Chemical, and Mitsui & Co.), and Unocal Canada (a subsidiary of the U.S. company, Unocal) formed a joint venture to recover yttrium and other rare earths as a byproduct of uranium processing at Denison's existing uranium operations at Elliot Lake, Ontario. The new separation plant, scheduled to open in late 1986, has a planned capacity of 150 tons per year of yttrium oxide in concentrates. Denison reportedly will sell its one-third share of the output to its partners. Union Oil of Canada's share is slated to go to another Unocal subsidiary, Molycorp, in the United States. Molycorp plans to produce high-purity yttrium oxide from the concentrate at its Louviers, CO, processing plant in the United States. Shin-Etsu is expected to refine its part of the concentrate at its plant in Takefu, Fukui, Japan.[20]

An analysis of the rare-earth content of the uranium leach solution at Elliott Lake was reported as follows.[21]

| Rare earth | Percent REO |
|---|---|
| Cerium | 3.7 |
| Dysprosium | 11.2 |
| Erbium | 5.5 |
| Europium | .2 |
| Gadolinium | 8.5 |
| Holmium | 2.6 |
| Lanthanum | .8 |
| Lutetium | .4 |
| Neodymium | 4.1 |
| Praseodymium | 1.0 |
| Samarium | 4.5 |
| Terbium | 1.2 |
| Thulium | .9 |
| Ytterbium | 4.0 |
| Yttrium | 51.4 |
| Total | 100.0 |

**China.**—A third rare-earth separation plant was completed at Baotou, Nei Monggol Autonomous Region, in June 1985. Baotou is the site of China's largest rare-earth processing operation and is supplied by the world's largest rare-earth deposit at Baiyunebo, 140 kilometers to the north. The new plant reportedly increased Baotou's production capacity for several separated rare-earth products, including neodymium oxide, the production capacity for which increased from 0.5 ton to 20 tons per year.[22]

**France.**—Rhône-Poulenc announced it would invest $26.7 million in its two rare-earth plants, one at La Rochelle, France, and the other at Freeport, TX, in the United States. The funds reportedly will be used to increase the existing separation and production capacities, especially for neodymium oxide and dysprosium oxide for use in high-strength permanent magnets.[23]

**Germany, Federal Republic of.**—Further studies of heavy minerals sands deposits at Cuxhaven, discovered during a drilling program in 1973-76, were concluded in 1985 by the Federal Ministry for Research and Technology. Reserves were estimated at 10 million tons of heavy minerals including ilmenite, rutile, zircon, and possibly monazite. The fossilized beach sands deposits are reportedly similar to those on the east coast of Australia, and were deposited during the late Tertiary era. Additional reserves are thought to occur in the area, and further exploration was scheduled.[24]

**India.**—Indian Rare Earths Ltd.'s dredge and wet concentrator plant began operation at the Orissa Sands Complex in Orissa. The dry mill was also commissioned and trial runs were being conducted.[25] Production of limited amounts of monazite concentrate associated with an initial production of 30,000 tons of ilmenite was reported.

**Japan.**—Imports of rare earths in 1985 were reported in the Japan Metal Journal, as follows:

| Product | Quantity (kilograms) |
|---|---|
| Cerium fluoride | 391 |
| Cerium oxide | 148,525 |
| Ferrocerium and other pyrophoric alloys | 30,550 |
| Lanthanum oxide | 188,360 |
| Rare-earth chloride | 5,889,427 |
| Rare-earth metals including yttrium and scandium | 58,966 |
| Yttrium oxide | 522,253 |

Principal sources of imported compounds were China, France, India, and the United States.

Data on Japanese consumption of rare earths in 1984 became available. Consumption was higher than that of 1983, and was reported as follows:[26] catalysts, 300 tons; cerium oxide, 2,100 tons; europium oxide, 8 tons; lanthanum oxide, 300 tons; mischmetal, 290 tons; rare-earth fluoride, 50 tons; samarium oxide, 250 tons; yttrium oxide, 210 tons; and other REO's, 150 tons.

Aimants Ugimag S.A., a subsidiary of the Pechiney Group of France, and Kawasaki Steel Corp., of Japan, formed a joint venture to manufacture rare-earth-cobalt magnets and other permanent magnets in Japan. The joint venture company, Nihon Ugimag Corp., will reportedly use Aimants Ugimag's permanent magnet technology. The plant was scheduled for completion in the fall of 1987.[27]

**Thailand.**—Monazite and xenotime were produced as byproducts of processing minerals sands for tin. Production data for 1985 were not available; production of xenotime concentrates through 1984 was as follows:[28]

| Year | Quantity (metric tons) |
|---|---|
| 1980 | 52 |
| 1981 | 45 |
| 1982 | 46 |
| 1983 | 38 |
| 1984 | 28 |

**U.S.S.R.**—A pilot plant for the recovery of precious metals and rare earths from seawater coolant was reportedly operating at a thermal powerplant in the eastern Soviet Union. Only small amounts of the metals were recovered, but the high value of the precious metals and some of the rare earths reportedly could make the plant economical.[29]

**Venezuela.**—Preliminary geological studies reportedly delineated economic concentrations of rare earths and niobium at Cerro Impacto, 120 miles southwest of Ciudad Bolivar, Bolivar State. Intense weathering, resulting from the region's tropical climate, has leached the original carbonatite source rock to produce thick lateritic beds with enrichment of rare earths and other elements. Rare-earth contents ranging from 0.1% to 11% were reported. Further investigation of the Cerro Impacto deposit was planned.

**Zaire.**—Several tin and gold deposits in the Kivu Region reportedly contain monazite. Reserves of monazite in the Obaye mining sector, under the jurisdiction of the Zairian mining company Société Minière et Industrielle de Kivu, occur in two separate deposits. The Kabengelwa deposit contains 2,100 tons of monazite (600 tons of REO equivalent) in ore grading 2.8 kilograms of heavy minerals sands per cubic meter. The Mashabuto deposit was reported to contain 45 tons of monazite (25 tons of REO equivalent) in ore grading 3 kilograms of heavy minerals sands per cubic meter.[30]

Table 5.—Monazite concentrate: World production, by country[1]

(Metric tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Australia | 13,282 | 9,562 | 15,141 | 16,702 | 15,000 |
| Brazil | [r]2,460 | [r]1,814 | 5,256 | 3,622 | 6,000 |
| India[e] [3] | [4]3,704 | 4,000 | 4,000 | 4,000 | 4,000 |
| Malaysia[5] | 320 | [r]546 | 1,051 | 4,451 | 6,000 |
| Mozambique | 4 | 3 | 4 | [e]4 | 4 |
| Sri Lanka | 60 | 304 | [e]300 | 147 | 200 |
| Thailand | 107 | 162 | 277 | 298 | 250 |
| United States | W | W | W | W | W |
| Zaire | 35 | 32 | 15 | 2 | -- |
| Total | [r]19,972 | [r]16,423 | 26,044 | 29,226 | 31,454 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Table includes data available through Apr. 29, 1986.

[2]In addition to the countries listed, China, Indonesia, North Korea, the Republic of Korea, Nigeria, and the U.S.S.R. may produce monazite, but output, if any, is not reported quantitatively, and available general information is inadequate for formulation of reliable estimates of output levels.

[3]Data are for years beginning Apr. 1 of that stated.

[4]Reported figure.

[5]The 1981-83 figures are exports and the 1984-85 figures are production.

## TECHNOLOGY

Researchers in China developed an improved hot-pressed silicon nitride (HPSN) ceramic with rare-earth additives that reportedly has high bend-strength and high fracture-toughness at elevated temperatures. Using rare-earth oxides as sintering aids, bend strengths of 800 to 900 megapascals were maintained up to 1,300° C. At 1,400° C, the ceramic's bend strength was 680 megapascals, reportedly one of the highest values obtained to date. The rare-earth-containing HPSN ceramic was said to represent a major advancement in ceramic material for use in high-temperature applications, such as internal combustion engines.[31]

Kubota and Japan's Agency of Industrial Science & Technology developed an improved silicon nitride ceramic, which reportedly was stronger at 1,000° C than at room temperature. Rare-earth oxides, including praseodymium and lanthanum, were listed as sintering additives.[32]

Rare-earth metals (REM) in continuously cast steels were reportedly responsible for improved ductility, weldability, fatigue resistance, and resistance to hydrogen damage. REM's, which are strong deoxidizers, were reportedly useful because they can be added to and retained in steel in any desired quantity, providing desulfurization and control of sulfide inclusions. Inclusions resulting from this shape control were beneficial in providing nuclei during solidification to promote fine-grained, as-cast structures. In addition to the refinement of as-cast structures, the rare earths reduced segregation and increased hot ductility at temperatures just below solidification.[33]

A high-temperature materials laboratory for research on advanced alloys and ceramic materials, including those containing rare earths, was under construction at Oak Ridge National Laboratory, Oak Ridge, TN, and was scheduled for completion in 1987. The laboratory's work was expected to be directed toward the development of improved alloys and nonbrittle ceramics that can withstand high temperatures and be suitable for use in gasoline and diesel engines, turbine blades, and other energy applications.[34]

A metal-vapor vacuum-arc ion source, developed by scientists at the University of California's Lawrence Berkeley Laboratory, produces heavy ions from a direct current arc generated between two high-melting-point electrodes, such as lanthanum. In the process, metal is vaporized and ionized at small regions of extremely intense current concentration, called cathode spots, on the negative electrode. A dense quasi-neutral plasma of cathode material is generated that diffuses away from the cathode in a plume from which a magnetically confined beam of ions is derived.[35]

A system for producing long pulses of ions from an arc discharge plasma and accelerating them through a series of grids that prevent backstreaming of electrons into the plasma chamber was developed using samarium-cobalt permanent magnets. The rare-earth-cobalt permanent magnets were used to confine the plasma, which generated up to 8.4 megawatts of power for pulsed lengths of 30 seconds. Developed by researchers at Lawrence Berkeley Laboratory, the device was expected to be installed at three major U.S. fusion research centers to serve as the primary energy source for heating reactor plasmas.[36]

A frequency-doubled 532-nanometer neodymium-yttrium-aluminum garnet (Nd:YAG) laser with a green beam was approved for medical use by the Food and Drug Administration. The new laser system was reportedly well received by the medical community and was being studied for applications in dermatology and plastic surgery, gynecology, neurosurgery, ophthalmology, otolaryngology, urology, and other applications. The green Nd:YAG laser's benefits are its generation of visible light; greater electrical efficiency than an argon laser, which emits near the same wavelength; a replaceable arc lamp that costs less than the corresponding large argon laser tube; the unique ability to display the laser energy being delivered to the patient and being measured at the end of the delivery device; an automatic calibration feature that allows the system to remain stable through an entire day's surgery; and the use of currently available optic fibers and probes. In clinical trials, the Nd:YAG laser system showed ease of control, good cutting, coagulating, and vaporizing properties, and less thermal damage than carbon dioxide or 1064-nanometer Nd:YAG lasers.[37]

Rare earths were used by researchers at Los Alamos National Laboratory in New Mexico to develop a cryogenic magnetic refrigerator. Applying the magneto-caloric effect (MCE), where materials held in a magnetic field cool down when the field is removed, gadolinium and gadolinium alloys were cooled from -423° F down to -452° F, using helium gas as the heat transfer fluid. Using fewer moving parts, magnetic refrigerators reportedly are two to four times more energy efficient than conventional refrigeration equipment. Future applications of MCE refrigeration could be in residential heat pumps, low-cost production of liquefied hydrogen, and energy storage devices.[38]

Rare earths were used to trace pollutants back to oil refineries. Highly-temperature-stable rare-earth-containing zeolites, used as fluid cracking catalysts (fcc) in the refining of oil, resist chemical transformation in the refining process and produce a recognizable pollutant signature in emissions. The distinctive ratio of rare-earth elements used in the fcc's reportedly permits identification of air masses originating from areas that have a high density of oil refineries.[39]

Researchers at Battelle Memorial Institute developed a low-cost method to produce zirconia powders, including those stabilized by yttrium oxide (yttria), by a hydrothermal process that eliminates the need for calcination. Battelle further developed the process to prepare powders with a narrow particle size distribution and particles down to 0.1 micrometer in diameter, with minimal agglomeration. Yttria-stabilized zirconia powder was produced that showed uniform distribution of yttria, which eliminated the need for diffusion, through calcination and sintering, to achieve homogeneity. The stabilized powder may be useful in advanced combustion engines because of its excellent wear resistance, fracture toughness, and mechanical strength.[40]

A composite insulation material containing yttria- or calcia-stabilized zirconia fibers was developed at the Oak Ridge National Laboratory. The composite insulation reportedly extends the operating temperature of metal-melting, oxide-fiber-lined furnaces from 1,700° C to 2,000° C. The yttria or calcia stabilizers allow tiny cracks to form in the zirconia fiber structures to release thermal stress.[41]

A research center was set up in Changsah, Hunan Province, China, to study further the use of rare earths in agriculture.[42] According to researchers in China, the addition of rare earths to the soil improves crop yields and raises the sugar content of certain vegetables. A pioneer in the development of rare earths for use in agriculture, China is expected to remain in the forefront of this technology as a result of its abundant reserves and low-cost production.

General Motors reported increased magnetic strengths in its neodymium-iron-boron (Nd-Fe-B) family of permanent magnets using a new process. The process strengthens the magnet by controlling heat and pressure to the die containing the jet-casted Nd-Fe-B alloy, so that the heat-softened ribbon of alloy can flow in a direction transverse to the pressing direction.[43] The new anisotropic permanent magnet material has magnetic strengths (BHmax) from 20 to 40 megagauss-oersteds.

Solid ionic-conducting trivalent beta aluminas containing rare-earth ions were studied for potential applications in optics, phosphors, and lasers, because they can serve as single-crystal or powder hosts. Solid ionic conductors, in which electrical conductivity is the result of ion movement, not electron movement, provide a greater density of electrical energy than aqueous solutions, with as high ionic diffusion rates. A solid-state laser system using trivalent neodymium beta alumina was developed in 1984, while ionic phosphors incorporating europium and terbium were reportedly under development. Currently, ion conductor technology is applied in oxygen sensors in automobiles where yttria-stabilized zirconia measures the partial pressure of oxygen in exhaust gases.[44]

Two Canadian physicians used erbium to filter ineffective but hazardous low-energy X-rays out of X-ray beams used in medical diagnosis. The erbium was reportedly used in foil filters and other shields to minimize X-ray exposure during fluoroscopy.[45]

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# Salt

### By Dennis S. Kostick[1]

Increased production and sales of rock salt and solar salt failed to offset the decrease in vacuum pan and open pan salt production and in salt brine production and use. This resulted in an overall decrease in total salt production and sales in 1985 compared with the levels recorded in 1984, which had been the best year for salt sales since 1980.

Apparent consumption of salt declined 3% primarily because of the decrease in salt consumption by certain sectors of the chemical industry that used salt as a feedstock. Salt sales reportedly increased for salt used as an ice control for highway deicing, for general industrial purposes, and in food processing. Although salt exports increased 10%, imports for consumption of salt decreased 18%.

**Domestic Data Coverage.**—Domestic production data for salt are developed by the Bureau of Mines from two voluntary surveys of U.S. operations. Typical of the surveys is the salt company survey. Of the 68 operations to which a survey request was sent, 60 responded, representing 98% of the total production shown in table 1. Production for the eight nonrespondents was estimated using reported 1984 production levels adjusted by trends in employment and other guidelines. Two producers reported no production.

**Table 1.—Salient salt statistics**

(Thousand short tons and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production[1] | 38,899 | 37,665 | 32,973 | 39,181 | 37,904 |
| Sold or used by producers[1] | 38,907 | 37,894 | 34,573 | 39,225 | 39,484 |
| Value | $637,568 | $671,424 | $597,081 | $675,099 | $741,799 |
| Exports | 1,046 | 1,001 | 517 | 820 | 904 |
| Value | $17,429 | $16,647 | $12,368 | $15,299 | $15,988 |
| Imports for consumption | 4,319 | 5,451 | 5,997 | 7,545 | 6,207 |
| Value | $44,523 | $56,184 | $60,194 | $74,100 | $65,593 |
| Consumption, apparent[2] | 42,180 | 42,344 | 40,053 | 45,950 | 44,787 |
| World: Production | [r]188,953 | [r]180,320 | 175,434 | [p]188,699 | [e]187,693 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Excludes Puerto Rico.

[2]Sold or used plus imports minus exports.

## DOMESTIC PRODUCTION

The total quantities of all types of salt produced by domestic producers decreased 3%. The amount sold or used remained virtually the same. In 1985, 39 companies operated 68 salt-producing plants in 14 States. Nine of the companies and 11 of the plants produced more than 1 million tons each, accounting for 80% and 63%, respectively, of the U.S. total. Many individual companies and plants produced more than one type of salt. By type of salt, the number of companies and operations, respectively, were solar, 11 and 14; vacuum pans and open pans, 8 and 18; rock, 11 and 15; and brine, 24 and 33.

The seven leading States in quantity of salt sold or used were Louisiana, 31%; Texas, 21%; New York, 18%; Ohio, 12%; Kansas, 5%; Utah and Michigan, about 3% each. A significant quantity of the salt produced in Alabama, Louisiana, New York, Texas, and West Virginia was produced as brine, of which the majority was captively consumed to manufacture chlorine, caustic soda, and soda ash. Although the quantity of salt brine used to manufacture chloralkalis decreased 9%, rock salt sales to the chloralkali industry increased 13%.

The percentage of salt sold or used by domestic producers, by type, was as follows:

| | 1984 | 1985 |
|---|---|---|
| Salt in brine | 50 | 46 |
| Mined rock | [r]34 | 37 |
| Vacuum pan salt and grainer or open pan salt | 9 | 10 |
| Solar-evaporated salt | [r]7 | 7 |
| Total | 100 | 100 |

[r] Revised.

International Salt Co. Inc. sold its Detroit salt mine in March to Crystal Mines Inc. Crystal Mines resumed public tours of the 73-year-old, 1,200-foot-deep mine but planned to convert it to a hazardous waste storage facility by 1987.[2] To encourage tourism and discourage possible hazardous waste pollution, local officials passed an ordinance regulating what could be stored in mines down to 200 feet below the Earth's surface.[3]

In April, Diamond Crystal Salt Co. acquired Hardy Salt Co., which had a vacuum pan operation in Michigan and a vacuum pan and brine facility in North Dakota. Morton Thiokol Inc. announced plans to increase rock salt production capacity by 250,000 tons at its Weeks Island, LA, operation. This expansion would partially offset the rock salt production capacity lost in Louisiana because of mine closures and accidents during the past several years. Cargill Inc. intentionally flooded its Belle Isle, LA, rock salt mine in November to eliminate the potential for roof collapse resulting from unsafe mining conditions, which had been the reason cited for the closure of the mine in 1984.

In September, FMC Corp. permanently closed its Bens Run, WV, chlorine and caustic soda facility, which included a salt brine operation. High energy costs and equipment obsolescence were cited as the reasons for the decision. The plant had been in continuous operation since 1915.[4]

A second chloralkali and salt brine facility was closed at yearend. Pennwalt Corp. in Wyandotte, MI, shut down its 100,000-ton-per-year plant as part of a major financial restructuring effort by the company.[5] The company planned to continue operation of its two other chloralkali plants in Oregon and Washington, which primarily used imported salt from Mexico as feedstock.

## Table 2.—Salt production in the United States

(Thousand short tons)

| Year | Vacuum pans and open pans | Solar | Rock | Brine | Total |
|---|---|---|---|---|---|
| 1981 | 3,800 | 2,393 | 11,871 | 20,835 | 38,899 |
| 1982 | 3,721 | 2,845 | 13,264 | 17,835 | 37,665 |
| 1983 | 3,697 | 2,053 | 9,449 | 17,774 | 32,973 |
| 1984 | 3,629 | 2,705 | 13,653 | 19,195 | [1]39,181 |
| 1985 | 3,618 | 2,734 | 13,819 | 17,738 | 37,904 |

[1] Data do not add to total shown because of independent rounding.

## Table 3.—Salt produced in the United States, by product form and type

(Thousand short tons)

| Product form | Vacuum pans and open pans | Solar | Rock | Brine | Total |
|---|---|---|---|---|---|
| 1984 | | | | | |
| Bulk | 676 | 1,953 | 13,032 | 19,195 | 34,856 |
| Compressed pellets | 824 | 53 | XX | XX | 877 |
| Packaged | 1,820 | 466 | 548 | XX | 2,834 |
| Pressed blocks | 309 | 233 | 73 | XX | 615 |
| Total[1] | 3,629 | 2,705 | 13,653 | 19,195 | 39,181 |
| 1985 | | | | | |
| Bulk | 666 | 2,006 | 13,226 | 17,738 | 33,636 |
| Compressed pellets | 818 | 60 | XX | XX | 878 |
| Packaged | 1,829 | 437 | 524 | XX | 2,790 |
| Pressed blocks | 299 | 231 | 69 | XX | 599 |
| Total[1] | 3,618 | 2,734 | 13,819 | 17,738 | 37,904 |

XX Not applicable.

[1] Data may not add to totals shown because of independent rounding.

## Table 4.—Salt sold or used in the United States, by type and product form

(Thousand short tons and thousand dollars)

| Product form | Vacuum pans and open pans | | Solar | | Rock | | Brine | | Total[1] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| 1984 | | | | | | | | | | |
| Bulk | 653 | 28,007 | 1,823 | 22,831 | 12,691 | 151,964 | 19,669 | 99,263 | 34,836 | 302,065 |
| Compressed pellets | 821 | 80,789 | 53 | 3,547 | XX | XX | XX | XX | 874 | 84,336 |
| Packaged: | | | | | | | | | | |
| Less-than-5-pound units | 157 | NA | 116 | NA | W | NA | XX | XX | [2]273 | NA |
| More-than-5-pound units | 1,684 | NA | 353 | NA | W | NA | XX | XX | [2]2,037 | NA |
| Total[1] | 1,841 | 198,775 | 468 | 19,743 | 593 | 31,059 | XX | XX | 2,903 | 249,577 |
| Pressed blocks: | | | | | | | | | | |
| For livestock | 191 | NA | 84 | NA | 71 | NA | XX | XX | 346 | NA |
| For water treatment | 118 | NA | 149 | NA | -- | NA | XX | XX | 267 | NA |
| Total | 309 | 23,390 | 233 | 10,034 | 71 | 5,697 | XX | XX | 613 | 39,121 |
| Grand total[1] | 3,624 | 330,961 | 2,578 | 56,154 | 13,355 | 188,720 | 19,669 | 99,263 | 39,225 | 675,099 |
| 1985 | | | | | | | | | | |
| Bulk | 676 | 27,810 | 2,050 | 29,336 | 13,948 | 202,406 | 18,127 | 118,304 | 34,801 | 377,856 |
| Compressed pellets | 822 | 75,717 | 60 | 4,183 | XX | XX | XX | XX | 882 | 79,900 |
| Packaged: | | | | | | | | | | |
| Less-than-5-pound units | 183 | NA | -- | NA | 56 | NA | XX | XX | 239 | NA |
| More-than-5-pound units | 1,902 | NA | 382 | NA | 588 | NA | XX | XX | 2,872 | NA |
| Total | 2,085 | 196,308 | 382 | 17,007 | 644 | 32,197 | XX | XX | 3,111 | 245,512 |
| Pressed blocks: | | | | | | | | | | |
| For livestock | 272 | NA | 75 | NA | 78 | NA | XX | XX | 425 | NA |
| For water treatment | 114 | NA | 159 | NA | 1 | NA | XX | XX | 274 | NA |
| Total | 386 | 22,772 | 234 | 10,179 | 79 | 5,580 | XX | XX | 699 | 38,531 |
| Grand total[1] | 3,969 | 322,607 | 2,725 | 60,705 | 14,669 | 240,183 | 18,127 | 118,304 | 39,484 | 741,799 |

NA Not available. W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.

[1] Data may not add to totals shown because of independent rounding.

[2] Excludes rock salt; included in "Packaged: Total."

### Table 5.—Salt sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

| State | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Kansas[1] | 1,712 | 71,558 | 1,790 | 71,970 |
| Louisiana | 13,101 | 112,142 | 12,325 | 138,955 |
| Michigan | 1,491 | 93,860 | 991 | 75,030 |
| New York | 5,644 | 123,755 | 6,928 | 142,318 |
| Ohio | W | W | 4,783 | 143,949 |
| Texas | 8,184 | 69,672 | 8,390 | 80,434 |
| Utah | 1,246 | 28,651 | 1,189 | 28,468 |
| West Virginia | 1,004 | W | 895 | W |
| Other[2] | 6,844 | 175,461 | 2,193 | 60,675 |
| Total | [3]39,225 | 675,099 | 39,484 | 741,799 |
| Puerto Rico[e] | 30 | 630 | 35 | 735 |

[e] Estimated. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Quantity and value of brine included with "Other."

[2] Includes Alabama, California, Kansas (brine only), Nevada, New Mexico, North Dakota, Oklahoma, and data indicated by symbol W.

[3] Data do not add to total shown because of independent rounding.

### Table 6.—Evaporated salt sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

| State | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Kansas | 906 | 62,505 | 876 | 61,986 |
| Louisiana | 203 | 18,510 | 205 | 18,612 |
| Michigan | 960 | 88,048 | 834 | 72,349 |
| New York | 661 | 60,631 | 1,073 | 64,510 |
| Utah | 1,173 | 27,752 | 1,129 | 27,314 |
| Other[1] | 2,306 | 129,789 | 2,733 | 152,601 |
| Total | 6,209 | [2]387,234 | 6,850 | 397,372 |
| Puerto Rico[e] | 30 | 630 | 35 | 735 |

[e] Estimated.

[1] Includes California, New Mexico, North Dakota, Ohio, Oklahoma, and Texas.

[2] Data do not add to total shown because of independent rounding.

## CONSUMPTION AND USES

Apparent consumption of all types of salt decreased 3% or about 1.2 million tons. Salt sales for highway deicing, general industrial purposes, and food processing were higher in 1985. The chemical industry, which traditionally has been the largest end-use market, required less salt for feedstock in 1985 than in previous years. Production of chlorine gas, sodium hydroxide, and metallic sodium, as reported by the Bureau of the Census, was as follows, in thousand short tons:

| | 1984[r] | 1985 |
|---|---|---|
| Chlorine gas (100%) | 10,700 | 10,465 |
| Sodium hydroxide, liquid (100%) | 10,914 | 10,959 |
| Sodium, metallic | 95 | [e]65 |

[e] Estimated. [r] Revised.

In October, the Wisconsin State Senate passed a bill that restricted the amount of salt used on streets and highways within the State. The legislation stipulated that no more than 300 pounds of salt would be used per lane mile per application, and the salt was to be applied only when the temperature was 10° F and above. The bill was in response to public concern about expensive damage to roads and bridges from salt corrosion and the effect of salt in public water supplies.[6] These factors were also cited by a Michigan State senator who requested a study on whether alternative compounds could be used for winter road deicing instead of rock salt.[7]

Of the 6.2 million tons of salt imports, approximately 2.6 million tons was directly imported and distributed by the domestic salt producers. The reported percent distri-

## Table 7.—Distribution of domestic and imported salt by producers in the United States, by end use and type

(Thousand short tons)

| End use | SIC | Vacuum pans and open pans | | Solar | | Rock | | Salt in brine | Total[1] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Domestic | Imported | Domestic | Imported | Domestic | Imported | | Domestic | Imported | Grand |
| 1984 | | | | | | | | | | | |
| Chemical: | | | | | | | | | | | |
| Chloralkali producers | 2812 | 24 | W | 226 | 438 | 1,365 | W | 18,086 | 19,702 | 440 | 20,142 |
| Other chemical | 28 (excludes 2812, 2899) | 306 | W | 114 | 32 | 684 | W | 100 | 1,204 | 54 | 1,258 |
| Total[1] | | 330 | W | 340 | 471 | 2,050 | W | 18,186 | 20,906 | 494 | 21,400 |
| Food processing industry: | | | | | | | | | | | |
| Meat packers | 201 | 163 | W | 34 | 9 | 254 | W | -- | 451 | 13 | 465 |
| Dairy | 202 | 91 | -- | 4 | 3 | 9 | (2) | -- | 104 | 4 | 107 |
| Canning | 2091, 203 | 125 | W | 39 | 25 | 78 | W | (2) | 242 | 25 | 267 |
| Baking | 205 | 113 | W | 3 | W | 8 | W | -- | 124 | 1 | 125 |
| Grain mill products | 204 (excludes 2047) | 54 | -- | 1 | W | 25 | W | -- | 80 | 2 | 81 |
| Other food processing | 206-208, 2047, 2099 | 131 | W | 14 | 8 | 43 | W | -- | 188 | 9 | 197 |
| Total[1] | | 677 | 3 | 95 | 45 | 417 | 5 | (2) | 1,189 | 54 | 1,242 |
| General industrial: | | | | | | | | | | | |
| Textiles and dyeing | 22 | 77 | W | W | 27 | 47 | W | W | 135 | 56 | 191 |
| Metal processing | 33, 34, 35, 37 | 32 | W | W | 11 | 259 | W | W | 309 | 17 | 326 |
| Rubber | 2822, 30 (excludes 3079) | 4 | -- | W | W | 5 | W | W | 41 | 1 | 42 |
| Oil | 13, 29 | 86 | -- | 273 | W | 74 | W | 427 | 862 | 10 | 870 |
| Pulp and paper | 26 | 12 | W | 170 | 29 | 117 | W | 7 | 307 | 30 | 337 |
| Tanning and/or leather | 311 | 9 | W | 12 | W | 64 | W | -- | 85 | 4 | 89 |
| Other industrial | | 64 | W | 46 | 29 | 57 | W | -- | 167 | 34 | 201 |
| Total[1] | | 285 | 31 | 528 | 111 | 623 | 9 | 469 | 1,904 | 151 | 2,055 |
| Agricultural: | | | | | | | | | | | |
| Feed retailers and/or dealers-mixers | | 371 | W | 161 | 36 | 392 | W | -- | 924 | 43 | 967 |
| Feed manufacturers | 2048 | 92 | -- | 66 | W | 186 | W | -- | 343 | 25 | 368 |
| Direct buying end users | 02 | 18 | -- | 15 | W | 46 | W | -- | 79 | 1 | 80 |
| Total[1] | | 481 | W | 242 | 61 | 624 | W | -- | 1,347 | 68 | 1,415 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water treatment:** | | | | | | | | | | | |
| Government (Federal, State, local) | 2899 | 8 | -- | 15 | W | 407 | W | (2) | 430 | 18 | 448 |
| Commercial or other | 2899 | 81 | -- | 269 | W | 47 | W | 4 | 401 | 12 | 413 |
| Total | | 89 | -- | 284 | 19 | 454 | 11 | 4 | 831 | 30 | 861 |
| **Ice control and/or stabilization:** | | | | | | | | | | | |
| Government (Federal, State, local) | 9621 | 6 | -- | 481 | 390 | 7,090 | 2,493 | -- | 7,576 | 2,882 | 10,458 |
| Commercial or other | | 6 | -- | 25 | 19 | 116 | 91 | 1 | 148 | 110 | 258 |
| Total[1] | | 11 | -- | 506 | 409 | 7,210 | 2,583 | 1 | 7,728 | 2,993 | 10,721 |
| **Distributors:** | | | | | | | | | | | |
| Agricultural distribution | 5159 | 84 | W | 64 | W | 102 | 40 | -- | 251 | 56 | 307 |
| Grocery wholesalers and/or retailers | 514, 54 | 619 | W | 88 | 68 | 153 | W | -- | 859 | 74 | 933 |
| Institutional wholesalers and end users. | 58, 70 | 35 | -- | W | 6 | 127 | 1 | W | 174 | 6 | 180 |
| Water conditioning distribution | 7399 | 264 | W | 121 | W | 287 | 219 | W | 672 | 408 | 1,087 |
| U.S. Government resale | 9199 | W | -- | W | -- | 532 | -- | W | 534 | -- | 534 |
| Other wholesalers and/or retailers | 5251 | 643 | W | 86 | 154 | 737 | W | 1 | 1,466 | 161 | 1,627 |
| Total[1] | | 1,645 | 6 | 369 | 431 | 1,939 | 268 | 9 | 3,962 | 705 | 4,667 |
| Other n.e.s.[3] | | 93 | W | 156 | 31 | 221 | W | 1,011 | 1,480 | 35 | 1,515 |
| Grand total[1] | | 3,609 | 49 | 2,522 | 1,578 | 13,538 | 2,902 | 19,680 | 39,349 | [4]4,529 | 43,878 |
| 1985 | | | | | | | | | | | |
| **Chemical:** | | | | | | | | | | | |
| Chloralkali producers | 2812 | 36 | W | 237 | W | 1,539 | W | 16,530 | 18,342 | 627 | 18,969 |
| Other chemical | 28 (excludes 2812, 2899) | 322 | W | 119 | W | 243 | W | 52 | 736 | 32 | 768 |
| Total | | 358 | 17 | 356 | 507 | 1,782 | 135 | 16,582 | 19,078 | 659 | 19,737 |
| **Food processing industry:** | | | | | | | | | | | |
| Meat packers | 201 | 178 | W | 34 | W | 202 | W | -- | 414 | 13 | 427 |
| Dairy | 202 | 122 | W | 3 | W | 4 | (2) | -- | 129 | 2 | 131 |
| Canning | 2091, 203 | 145 | W | 32 | W | 83 | W | 1 | 261 | 19 | 280 |
| Baking | 205 | 127 | W | 3 | W | 7 | W | -- | 137 | 1 | 138 |
| Grain mill products | 204 (excludes 2047) | 65 | -- | 1 | W | 25 | W | -- | 91 | 1 | 92 |
| Other food processing | 206-208, 2047, 2099 | 150 | W | 23 | W | 41 | W | -- | 214 | 13 | 227 |
| Total | | 787 | 6 | 96 | 28 | 362 | 15 | 1 | 1,246 | 49 | 1,295 |

See footnotes at end of table.

## Table 7.—Distribution of domestic and imported salt by producers in the United States, by end use and type —Continued

(Thousand short tons)

| End use | SIC | Vacuum pans and open pans |  | Solar |  | Rock |  | Salt in brine | Total[1] |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Domestic | Imported | Domestic | Imported | Domestic | Imported |  | Domestic | Imported | Grand |
| 1985 —Continued |  |  |  |  |  |  |  |  |  |  |  |
| General industrial: |  |  |  |  |  |  |  |  |  |  |  |
| Textiles and dyeing | 22 | 70 | W | 7 | W | 47 | (2) | 2 | 126 | 47 | 173 |
| Metal processing | 33, 34, 35, 37 | 29 | W | 11 | W | 335 | 1 | W | 375 | 5 | 380 |
| Rubber | 2822, 30 (excludes 3079) | 4 | -- | 1 | W | 5 | W | 32 | 42 | (2) | 42 |
| Oil | 13, 29 | 86 | -- | 372 | W | 78 | W | 445 | 976 | 3 | 979 |
| Pulp and paper | 26 | 19 | W | 176 | W | 77 | W | 7 | 279 | 15 | 294 |
| Tanning and/or leather | 311 | 10 | W | 10 | W | 71 | W | -- | 91 | 4 | 95 |
| Other industrial |  | 74 | W | 49 | W | 57 | 5 | W | 180 | 8 | 188 |
| Total | -------- | 292 | 83 | 626 | 39 | 665 | 11 | 487 | 2,069 | 83 | 2,151 |
| Agricultural: |  |  |  |  |  |  |  |  |  |  |  |
| Feed retailers and/or dealers-mixers |  | 433 | W | 127 | W | 339 | W | 1 | 900 | 22 | 922 |
| Feed manufacturers | 2048 | 95 | W | 71 | W | 226 | W | -- | 392 | 2 | 394 |
| Direct buying end users | 02 | 19 | -- | 15 | W | 19 | W | -- | 53 | (2) | 53 |
| Total | -------- | 547 | 7 | 213 | 9 | 584 | 7 | 1 | 1,345 | 24 | 1,369 |
| Water treatment: |  |  |  |  |  |  |  |  |  |  |  |
| Government (Federal, State, local) | 2899 | 9 | W | 23 | W | 215 | W | 2 | 249 | 8 | 257 |
| Commercial or other | 2899 | 83 | -- | 271 | W | 53 | W | 17 | 424 | 2 | 426 |
| Total | -------- | 92 | W | 294 | 7 | 268 | W | 19 | 673 | 10 | 683 |
| Ice control and/or stabilization: |  |  |  |  |  |  |  |  |  |  |  |
| Government (Federal, State, local) | 9621 | 6 | W | 517 | W | 8,951 | 1,383 | 1 | 9,475 | 1,402 | 10,877 |
| Commercial or other |  | 12 | W | 11 | W | 329 | 66 | -- | 352 | 69 | 421 |
| Total | -------- | 18 | W | 528 | 22 | 9,280 | 1,449 | 1 | 9,827 | 1,471 | 11,298 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Distributors: | | | | | | | | | | | |
| Agricultural distribution | 5159 | 134 | W | 59 | W | 123 | W | -- | 316 | 59 | 375 |
| Grocery wholesalers and/or retailers | 514, 54 | 621 | W | 77 | W | 151 | W | -- | 849 | 29 | 878 |
| Institutional wholesalers and end users. | 58, 70 | 30 | W | 10 | W | 135 | 25 | -- | 175 | 30 | 205 |
| Water conditioning distribution | 7399 | 264 | W | 75 | W | 253 | W | (²) | 593 | 45 | 638 |
| U.S. Government resale | 9199 | 8 | -- | 1 | (²) | 5 | -- | -- | 14 | (²) | 14 |
| Other wholesalers and/or retailers | 5251 | 665 | W | 43 | W | 678 | 11 | -- | 1,386 | 80 | 1,466 |
| Total | | 1,722 | W | 265 | W | 1,345 | 52 | (²) | 3,332 | 243 | 3,575 |
| Other n.e.s.³ | | 153 | W | 341 | W | 383 | 10 | 1,087 | 1,914 | 29 | 1,943 |
| Grand total¹ | | 3,969 | 86 | 2,725 | 799 | 14,669 | 1,681 | 18,127 | 39,484 | ⁴2,568 | 42,052 |

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Data may not add to totals shown because of independent rounding. Data may differ from totals shown in tables 1, 4, 5, 6, and 8 because of changes in inventory and/or incomplete data reporting.

[2] Less than 1/2 unit.

[3] Includes exports.

[4] Imported for distribution by U.S. producers; included in tables 12, 13, and 14.

## Table 8.—Distribution of domestic and imported evaporated and rock salt[1] in the United States, by destination

(Thousand short tons)

| Destination | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Evaporated | | Rock | Evaporated | | Rock |
| | Vacuum pans and open pans | Solar | | Vacuum pans and open pans | Solar | |
| Alabama | 49 | W | 705 | 47 | (1) | 511 |
| Alaska | (1) | 22 | -- | (1) | 6 | -- |
| Arizona | 5 | 46 | 8 | 6 | 15 | 6 |
| Arkansas | 29 | (1) | 81 | 29 | (1) | 97 |
| California | 136 | 795 | 7 | 145 | 1,026 | 1 |
| Colorado | 18 | 124 | 70 | 19 | 122 | 44 |
| Connecticut | 11 | 23 | 204 | 15 | W | 212 |
| Delaware | 3 | 177 | 8 | 3 | 152 | 9 |
| District of Columbia | 1 | 4 | 1 | 1 | -- | W |
| Florida | 77 | 55 | 37 | 82 | W | 34 |
| Georgia | 64 | 22 | 85 | 59 | W | 85 |
| Hawaii | 2 | (1) | W | W | W | (1) |
| Idaho | 5 | 75 | 5 | 6 | 75 | W |
| Illinois | 351 | 51 | 1,595 | 425 | 45 | 1,200 |
| Indiana | 152 | 22 | 856 | 173 | 19 | 872 |
| Iowa | 167 | 43 | 341 | 177 | 25 | 291 |
| Kansas | 95 | 11 | 260 | 98 | 11 | 331 |
| Kentucky | 35 | (1) | 428 | 42 | (1) | 489 |
| Louisiana | 56 | W | 365 | 71 | 3 | 67 |
| Maine | 7 | 12 | 219 | 7 | W | 175 |
| Maryland | 43 | 229 | 142 | 52 | W | 70 |
| Massachusetts | 35 | 74 | 442 | 33 | W | 536 |
| Michigan | 221 | 26 | 1,371 | 257 | 16 | 1,225 |
| Minnesota | 148 | 95 | 439 | 165 | 58 | 346 |
| Mississippi | 23 | W | 125 | 23 | -- | 123 |
| Missouri | 103 | 17 | 434 | 118 | 17 | 463 |
| Montana | 4 | 39 | 5 | 8 | 27 | W |
| Nebraska | 89 | 27 | 115 | 81 | 28 | 144 |
| Nevada | 1 | 167 | 8 | W | 166 | W |
| New Hampshire | 2 | 6 | 86 | W | (1) | W |
| New Jersey | 124 | 131 | 291 | 130 | 31 | 212 |
| New Mexico | 8 | 124 | 2 | 8 | 127 | 2 |
| New York | 242 | 63 | 2,304 | 245 | W | 2,376 |
| North Carolina | 123 | 78 | 86 | 144 | -- | 46 |
| North Dakota | 45 | 37 | 3 | 82 | 34 | 2 |
| Ohio | 309 | 11 | 1,760 | 321 | 15 | 2,368 |
| Oklahoma | 55 | 9 | 72 | 47 | 10 | 89 |
| Oregon | [r]11 | 33 | W | 11 | 91 | -- |
| Pennsylvania | 162 | 100 | [r]1,191 | 170 | 30 | 1,175 |
| Rhode Island | 5 | 43 | 39 | 5 | 1 | 77 |
| South Carolina | 34 | [r]17 | 14 | 38 | W | 13 |
| South Dakota | 42 | 34 | 42 | 42 | 31 | 38 |
| Tennessee | 63 | (1) | 547 | 64 | (1) | 778 |
| Texas | 154 | [r]77 | 265 | 162 | 89 | 204 |
| Utah | 4 | 368 | 39 | W | 367 | W |
| Vermont | 5 | 1 | 204 | 5 | W | 164 |
| Virginia | 62 | 103 | 105 | 66 | W | 79 |
| Washington | 18 | 517 | W | W | 636 | -- |
| West Virginia | 16 | [r]5 | 138 | 15 | (1) | 214 |
| Wisconsin | 215 | 35 | 917 | 299 | 30 | 320 |
| Wyoming | (1) | 33 | (1) | (1) | 30 | (1) |
| Other[2] | [r]32 | [r]124 | [r]335 | 56 | 376 | 199 |
| Total[3] | [r]3,661 | [r]4,105 | [r]16,796 | 4,052 | 3,709 | [4]15,685 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Less than 1/2 unit.

[2] Includes shipments to overseas areas administered by the United States, Puerto Rico, exports, some shipments to unspecified destinations, and shipments to States indicated by symbol W.

[3] Data may differ from totals shown in tables 1, 4, 5, 6, and 7 because of imports, changes in inventory, and/or incomplete data reporting.

[4] Data do not add to total shown because of independent rounding.

bution of salt by major end use in 1985 was chemicals, 47%; ice control, 27%; distributors, 8%; industrial, 5%; food and agricultural, 3% each; water treatment, 2%; and other, 5%. In table 7, specific sectors of distribution, such as agricultural and water conditioning, can be combined with the primary agricultural and water treatment categories for a complete end-use analysis.

The use of salt in ion exchange water softening units was investigated as part of a study linking water softness with cardiovascular disease. Researchers at the Health Effects and Epidemiology Section of the Oak Ridge National Laboratory concluded that people who drank naturally soft water containing low concentrations of calcium and magnesium—two elements that largely gauge water hardness—had a greater risk of contracting heart disease. However, artificially softened water using salt apparently does not contribute to the risk.[8]

## STOCKS AND PURCHASES

Total yearend stocks reported by producers decreased from 2.7 million tons in 1984 to 2.5 million tons in 1985. Most of these stocks were rock salt and solar salt. An unknown quantity of salt for road and highway deicing was usually stored in anticipation of adverse winter conditions by many States, municipalities, distributors, and road deicing contractors.

Intraindustry salt purchases of salt amounted to 3.1 million tons, of which 39% was rock salt; brine, 34%; solar, 23%; and vacuum pans and open pans, 4%.

## PRICES

Price quotations are not synonymous with average values reported to the Bureau of Mines. The quotations do not necessarily represent prices at which transactions actually occurred, nor do they represent bid and asked prices. They are quoted here to serve only as a reference to yearend price levels. The following yearend salt prices were quoted in Chemical Marketing Reporter:[9]

| | |
|---|---|
| Salt, evaporated, common, 80-pound bags, carlots or truckloads, North, works, 80 pounds | $4.02 |
| Salt, chemical-grade, same basis, 80 pounds | 4.30 |
| Salt, rock, medium coarse, same basis, 80 pounds | 2.70 |
| Bulk, same basis, per ton | 25.00 |

Table 9 represents the average values of different types and product forms of salt, f.o.b. works, based on actual sales by producers.

### Table 9.—Average values[1] of salt, by product form and type

(Dollars per short ton)

| Product form | Vacuum pans and open pans | Solar | Rock | Brine |
|---|---|---|---|---|
| 1984 | | | | |
| Bulk | 42.89 | 12.52 | 11.97 | 5.05 |
| Compressed pellets | 98.40 | 66.92 | XX | XX |
| Packaged | 107.97 | 42.10 | 52.38 | XX |
| Average[2] | 92.78 | 19.67 | 13.78 | 5.05 |
| Pressed blocks | 75.70 | 43.06 | 80.24 | XX |
| 1985 | | | | |
| Bulk | 41.14 | 14.31 | 14.51 | 6.53 |
| Compressed pellets | 92.11 | 69.72 | XX | XX |
| Packaged | 94.15 | 44.52 | 50.00 | XX |
| Average[2] | 83.68 | 20.28 | 16.08 | 6.53 |
| Pressed blocks | 59.00 | 43.50 | 70.63 | XX |

XX Not applicable.

[1] Net selling value, f.o.b. plant, excluding container costs.

[2] Salt value data previously reported were an aggregate value per ton of bulk, compressed pellets, and packaged salt. For time series continuity, an average of these three types of product forms is presented, which is based on the aggregated values and quantities of the product form for each type of salt shown in table 4.

## FOREIGN TRADE

The United States imported nearly seven times the amount of salt it exported. Exports of salt to Canada represented about 98% of the total U.S. export market; the balance was distributed to 47 other countries.

Approximately 99% of total salt imports was bulk rock salt and solar salt. The Bahamas, Canada, and Mexico supplied 78% of the total imports. Imports of salt in bags, sacks, barrels, and brine, primarily from Canada, the Republic of Korea, and Mexico, represented the remainder.

In response to a petition filed by International Salt, the International Trade Administration of the U.S. Department of Commerce preliminarily determined that Canadian rock salt was being sold in the United States at less than fair value, thereby materially injuring domestic rock salt producers. Domtar Inc. and Morton Thiokol, the parent company of Canadian Salt Co., accounted for as much as 70% of the U.S. imports from Canada. The case was submitted to the U.S. International Trade Commission for a final determination by the end of January 1986.[10]

**Table 10.—Salt shipped to the Commonwealth of Puerto Rico and the Virgin Islands**

| Area | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Puerto Rico | 18,000 | $2,300 | 22,990 | $5,196 |
| Virgin Islands | 1 | 1 | -- | -- |

Source: Annual FT800 U.S. Trade with Puerto Rico and U.S. Possessions, Bureau of the Census.

**Table 11.—U.S. exports of salt, by country**

(Thousand short tons and thousand dollars)

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value |
| Australia | (1) | 25 | (1) | 3 |
| Bahamas | 2 | 235 | 1 | 86 |
| Canada | 792 | 11,534 | 883 | 12,313 |
| Costa Rica | (1) | 27 | (1) | 4 |
| Denmark | 3 | 46 | 1 | 35 |
| Honduras | (1) | 21 | (1) | 21 |
| Hong Kong | (1) | 3 | -- | -- |
| Iraq | -- | -- | 1 | 190 |
| Malaysia | (1) | 1 | -- | -- |
| Mexico | 7 | 382 | 5 | 302 |
| Netherlands Antilles | 1 | 98 | (1) | 105 |
| Saudi Arabia | 10 | 1,970 | 9 | 1,930 |
| South Africa, Republic of | (1) | 1 | (1) | 16 |
| Trinidad and Tobago | (1) | 66 | (1) | 17 |
| United Arab Emirates | (1) | 49 | (1) | 54 |
| United Kingdom | 1 | 152 | 1 | 216 |
| Venezuela | (1) | 10 | (1) | 2 |
| Other | 4 | 679 | 3 | 694 |
| Total | 820 | 15,299 | 904 | 15,968 |

(1) Less than 1/2 unit.

Source: Bureau of the Census as adjusted by the Bureau of Mines.

## Table 12.—U.S. imports for consumption of salt

(Thousand short tons and thousand dollars)

| Year | In bags, sacks, barrels, or other packages (dutiable) | | Bulk (dutiable) | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| 1982 | 47 | 1,613 | [1]5,404 | [1]54,571 |
| 1983 | 30 | 1,826 | [2]5,967 | [2]58,368 |
| 1984 | 71 | 2,386 | [3]7,474 | [3]71,714 |
| 1985 | 66 | 3,794 | [4]6,141 | [4]61,799 |

[1] Includes salt brine from Canada through Portland, ME, and St. Albans, VT, customs districts, 26 short tons ($377) and 55 short tons ($2,698), respectively; from Chile through Wilmington, NC, customs district, 100 pounds ($350); and from the United Kingdom through Washington, DC, customs district, 200 pounds ($2,152).

[2] Includes salt brine from Canada through Buffalo, NY, customs district, 400 pounds ($610); from Mexico through Laredo, TX, customs district, 18 short tons ($1,126); from Denmark through Cleveland, OH, customs district, 100 pounds ($269); from the United Kingdom through Baltimore, MD, customs district, 100 pounds ($1,209); from Ireland through New York, NY, customs district, 15 short tons ($300); and from Japan through Seattle, WA, customs district, 1,300 pounds ($392).

[3] Includes salt brine from Iceland, the United Kingdom, and Hong Kong through New York, NY, customs district, 500 pounds ($940); from Norway and the Federal Republic of Germany through Chicago, IL, customs district, 110 short tons ($3,299); from Denmark through Detroit, MI, customs district, 23 short tons ($191); and from Japan through Charleston, SC, customs district, 110 pounds ($527).

[4] Includes salt brine from Spain through New York, NY, customs district, 1,987 short tons ($27,620); from Denmark through Cleveland, OH, customs district, 935 short tons ($76,714); from Japan through Charleston, SC, customs district, 691 short tons ($4,620); from Switzerland through Chicago, IL, customs district, 28 short tons ($2,533); and from the Federal Republic of Germany through Washington, DC, customs district, an undisclosed quantity valued at $5,444.

Source: Bureau of the Census as adjusted by the Bureau of Mines.

## Table 13.—U.S. imports for consumption of salt, by country

(Thousand short tons and thousand dollars)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Bahamas | 902 | 9,163 | 952 | 10,301 |
| Brazil | 304 | 2,567 | 70 | 642 |
| Canada[1] | 3,279 | 27,511 | 2,670 | 21,916 |
| Chile | 479 | 4,089 | 280 | 2,828 |
| France[2] | 114 | 896 | 199 | 1,967 |
| Germany, Federal Republic of[3] | 1 | 70 | 2 | 135 |
| Italy[4] | -- | -- | 55 | 430 |
| Mexico[5] | 1,519 | 22,794 | 1,230 | 18,657 |
| Netherlands | 236 | 2,535 | 90 | 2,149 |
| Netherlands Antilles | 275 | 2,527 | 191 | 2,440 |
| Spain[6] | 418 | 1,503 | 402 | 3,188 |
| Other | 16 | 444 | 67 | 941 |
| Total[7] | 7,545 | 74,100 | 6,207 | 65,593 |

[1] Includes salt in bags, sacks, and barrels through 10 customs districts, 27,780 short tons ($1,716,050) in 1984; and 11 customs districts, 40,691 short tons ($2,769,497) in 1985.

[2] Includes salt in bags, sacks, and barrels through four customs districts, 567 short tons ($13,263) in 1984; and four customs districts, 128 short tons ($38,356) in 1985.

[3] Includes salt in bags, sacks, and barrels through five customs districts, 562 short tons ($67,446) in 1984; and four customs districts, 2,084 short tons ($120,114) in 1985.

[4] Includes salt in bags, sacks, and barrels through two customs districts, 1 short ton ($5,160) in 1985.

[5] Includes salt in bags, sacks, and barrels through three customs districts, 29,218 tons ($306,502) in 1984; and three customs districts, 14,762 short tons ($148,417) in 1985.

[6] Includes salt in bags, sacks, and barrels through one customs district, 3 short tons, ($3,933) in 1984; and one customs district, 22 short tons ($145,725) in 1985.

[7] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census as adjusted by the Bureau of Mines.

### Table 14.—U.S. imports for consumption of salt, by customs district

(Thousand short tons and thousand dollars)

| Customs district | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Anchorage, AK | ([1]) | 36 | 17 | 272 |
| Baltimore, MD | 573 | 2,587 | 418 | 3,686 |
| Boston, MA | 167 | 1,167 | 78 | 1,325 |
| Buffalo, NY | 66 | 552 | 1 | 67 |
| Chicago, IL | 787 | 5,938 | 590 | 4,070 |
| Cleveland, OH | 25 | 298 | 92 | 721 |
| Detroit, MI | 921 | 9,219 | 991 | 9,766 |
| Duluth, MN | 155 | 1,433 | 114 | 887 |
| Los Angeles, CA | 121 | 2,178 | 127 | 1,082 |
| Milwaukee, WI | 616 | 4,386 | 706 | 3,343 |
| New Orleans, LA | 237 | 1,865 | 148 | 1,593 |
| New York, NY | 645 | 6,760 | 404 | 6,234 |
| Norfolk, VA | 46 | 501 | 114 | 951 |
| Ogdensburg, NY | 24 | 542 | 5 | 92 |
| Philadelphia, PA | 182 | 2,567 | 216 | 2,505 |
| Portland, ME | 571 | 5,378 | 461 | 3,787 |
| Portland, OR | 589 | 7,648 | 506 | 7,049 |
| Providence, RI | 94 | 959 | 18 | 629 |
| St. Albans, VT | 75 | 841 | 6 | 142 |
| San Juan, PR | 7 | 189 | 10 | 269 |
| Savannah, GA | 467 | 4,559 | 400 | 3,398 |
| Seattle, WA | 658 | 6,165 | 508 | 9,580 |
| Tampa, FL | 86 | 902 | 89 | 760 |
| Wilmington, NC | 165 | 2,779 | 207 | 3,207 |
| Other | 268 | 4,656 | 2 | 176 |
| Total | 7,545 | 74,100 | 6,207 | [2]65,593 |

[1] Less than 1/2 unit.

[2] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census as adjusted by the Bureau of Mines.

## WORLD REVIEW

**Canada.**—Seleine Mines Inc., wholly owned by Société Québécoise d'Exploration Minière (SOQUEM), which is the Quebec government's mining company, sought a partner to assume a 40% interest or to buy its rock salt mine on the St. Magdalen Islands in the Gulf of the St. Lawrence River. Production problems that affected profitability were cited as the reason SOQUEM needed a partner with the capital necessary to finance mine improvements. Unless a partner or buyer was found, the Government could decide to close the mine that produced 1 million tons of rock salt per year and employed 180 people.[11]

**Nigeria.**—The Nigerian Mining Corp. and the National Chemical Co. announced plans to coproduce food-grade and industrial salt. The salt would be used for domestic consumption and for export.[12]

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[1] Physical scientist, Division of Industrial Minerals.

[2] Edwards, R. Salt Mine Tours Slated: Owner Eyes Dump Setup. The Detroit News, v. 2, No. 10, June 15, 1985, p. 2c.

[3] Michigan Press (Williamston). New Ordinance Governs Use of Underground Mines. Mar. 27, 1985, p. A3.

[4] Virgin, B. Future of FMC's S.C. Plant in Doubt. Daily Mail (Charleston, WV), July 9, 1985, p. A4.

[5] Chemical Week. Pennwalt Closes a Chlorine/Caustic Unit. V. 135, No. 15, 1985, pp. 14-16.

[6] News-Tribune and Herald (Duluth, MN). Wisconsin Senate Passes Bill Restricting Use of Road Salt. V. 110, No. 21, Oct. 18, 1985, p. 10.

[7] The Mining Journal (Marquette, MI). Salt Study Urged. V. 16, No. 25, Dec. 12, 1985, p. 1A.

[8] Science News. Soft Water and Heart Disease. V. 127, No. 25, 1985, p. 189.

[9] Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 228, No. 27, Dec. 30, 1985, p. 43.

[10] ———. Rock Salt Dumping Found Against Canada. V. 228, No. 4, July 22, 1985, p. 7.

[11] Toomey, C. Six Salt Producers Eye Soquem Mine. The Gazette (Toronto, Canada), v. 15, No. 10, Nov. 2, 1985, p. H3.

[12] Industrial Minerals (London). Company News and Mineral Notes. No. 218, 1985, p. 81.

### Table 15.—Salt: World production, by country[1]

(Thousand short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Afghanistan[e] | 7 | 11 | 11 | 11 | 11 |
| Albania[e] | 75 | 75 | 80 | 80 | 80 |
| Algeria | 141 | 154 | [e]165 | 193 | 200 |
| Angola[e] | 55 | 65 | 60 | 55 | 11 |
| Argentina: | | | | | |
| Rock salt | 1 | 1 | 1 | 1 | 1 |
| Other salt | 1,033 | 655 | 746 | 1,033 | 880 |
| Australia (marine salt and brine salt) | 7,403 | 5,303 | 5,699 | [e]5,500 | 5,500 |
| Austria: | | | | | |
| Rock salt | 1 | 1 | 1 | 1 | 1 |
| Evaporated salt | 509 | 478 | 396 | 462 | 460 |
| Salt in brine | 291 | 236 | 155 | 263 | 250 |
| Bahamas | 1,069 | 899 | 950 | [e]960 | 940 |
| Bangladesh[3] | 304 | 634 | 268 | 741 | 660 |
| Benin | (4) | (4) | (4) | (4) | (4) |
| Brazil: | | | | | |
| Rock salt | 925 | 922 | [5]1,023 | 1,046 | 1,050 |
| Marine salt | 3,049 | 3,183 | [5]3,592 | 3,944 | 4,080 |
| Bulgaria | 93 | 97 | 95 | 98 | [e]99 |
| Burma[7] | 298 | 297 | 317 | 309 | 310 |
| Cambodia (Kampuchea) | 27 | 42 | [e]45 | [e]45 | 45 |
| Canada | 7,981 | 8,752 | 9,482 | 11,282 | 11,070 |
| Chile | 320 | 748 | 788 | 690 | [e]831 |
| China | 20,194 | 18,060 | [e]17,780 | [r] [e]17,950 | 15,900 |
| Colombia: | | | | | |
| Rock salt | 349 | 331 | 293 | [e]300 | 280 |
| Marine salt | 440 | 223 | 321 | 517 | 440 |
| Costa Rica (marine salt)[e] | 43 | [e]121 | 120 | 120 | 120 |
| Cuba | 177 | 218 | 198 | 203 | 200 |
| Cyprus | 10 | 11 | -- | -- | -- |
| Czechoslovakia | 343 | 360 | 265 | 268 | 270 |
| Denmark[6] | 439 | 440 | 498 | 576 | [e]633 |
| Dominican Republic[e] | 70 | 70 | 70 | 70 | 70 |
| Egypt | 748 | 918 | 1,012 | [e]1,100 | 1,100 |
| El Salvador[e] | 2 | 2 | 2 | 2 | 3 |
| Ethiopia:[e] [3] | | | | | |
| Rock salt[e] | 17 | 17 | 17 | 17 | 17 |
| Marine salt | [e]121 | 121 | 121 | [r]130 | 130 |
| France: | | | | | |
| Rock salt | 328 | 421 | 311 | 249 | 250 |
| Brine salt | 1,204 | 1,181 | 1,184 | [e]1,200 | 1,200 |
| Marine salt | 1,517 | 1,696 | 1,494 | 1,522 | 1,540 |
| Salt in solution | 4,266 | 4,091 | 4,673 | [e]4,740 | 4,850 |
| German Democratic Republic: | | | | | |
| Rock salt[e] | [e]3,369 | [e]3,370 | 3,380 | [r]3,390 | 3,300 |
| Marine salt | 62 | 61 | 62 | 64 | 60 |
| Germany, Federal Republic of: Marketable: | | | | | |
| Rock salt | 9,223 | 7,754 | 6,906 | [e]7,700 | 7,200 |
| Marine salt and other salt | 4,601 | 4,348 | 4,560 | [e]4,600 | 4,400 |
| Ghana[e] | 55 | 55 | 55 | 55 | 55 |
| Greece | 145 | 128 | 176 | [r] [e]150 | 180 |
| Guatemala | 15 | [e]15 | 17 | [r] [e]18 | 18 |
| Honduras[e] | 35 | 35 | 35 | 35 | 35 |
| Iceland | (4) | (4) | 1 | 1 | [e]1 |
| India: | | | | | |
| Rock salt | [e]4 | 5 | 5 | [e]6 | 6 |
| Marine salt | 9,841 | 7,758 | 7,725 | 8,514 | 8,300 |
| Indonesia | [r]295 | [r]1,387 | 681 | 408 | 660 |
| Iran[e] [8] | 660 | 770 | 830 | 830 | 830 |
| Iraq[e] | [e]88 | 90 | 90 | 90 | 80 |
| Israel | 146 | 163 | [e]160 | [e]160 | 170 |
| Italy: | | | | | |
| Rock salt and brine salt | 3,979 | 3,974 | 3,807 | 3,588 | [e]3,500 |
| Marine salt[e] | 1,060 | 1,100 | 1,200 | 1,100 | 1,100 |
| Japan[e] | 1,105 | 1,065 | 1,015 | [e]1,300 | 1,300 |
| Jordan[e] | 33 | 55 | 90 | 90 | 90 |
| Kenya: | | | | | |
| Rock[e] | 30 | 50 | 70 | [e]80 | 83 |
| Other | [e]23 | 27 | [e]26 | 31 | 33 |
| Korea, North[e] | 630 | 630 | 630 | 630 | 630 |
| Korea, Republic of | 664 | 952 | 530 | 709 | 720 |
| Kuwait | 21 | 21 | [e]22 | 23 | [e]23 |
| Laos[e] | 22 | [e]10 | 11 | 11 | 11 |
| Lebanon[e] | 17 | 11 | 6 | 6 | 6 |
| Leeward and Windward Islands[e] | 55 | 55 | 55 | 55 | 55 |
| Libya[e] | 11 | 11 | 13 | 13 | 11 |
| Madagascar[e] | 33 | 33 | 33 | 33 | 33 |
| Mali[e] | 5 | 5 | 5 | 5 | 5 |
| Malta | (4) | (4) | (4) | (4) | (4) |
| Mauritania[e] | -- | [e]8 | 6 | 6 | 6 |

See footnotes at end of table.

## Table 15.—Salt: World production, by country[1] —Continued

(Thousand short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Mauritius | 7 | 7 | [e]7 | [e]7 | 7 |
| Mexico | 8,767 | 6,130 | 6,287 | 6,787 | 6,600 |
| Mongolia[e] | 17 | 17 | 18 | 18 | 18 |
| Morocco | [r]61 | [r]62 | 77 | 69 | 70 |
| Mozambique[e] | 30 | 30 | 30 | 30 | 30 |
| Namibia (marine salt) | 213 | 208 | 151 | 97 | [e]168 |
| Netherlands | 3,944 | 3,517 | 3,444 | 4,050 | 4,300 |
| Netherlands Antilles[e] | [r]240 | [r]300 | 220 | [r]390 | 390 |
| New Zealand | 61 | 77 | 80 | 63 | 70 |
| Nicaragua[e] | 20 | 20 | 20 | 17 | 17 |
| Niger[e] | 3 | [e]3 | 3 | 3 | 3 |
| Pakistan:[3] | | | | | |
| Rock salt | [r]564 | [r]594 | 629 | 659 | 630 |
| Other salt | [r]202 | [r]246 | [r] [e]210 | [r] [e]200 | [e]244 |
| Panama (crude) | 35 | 27 | 94 | [e]100 | 100 |
| Peru | 558 | 535 | [e]540 | [e]550 | 550 |
| Philippines | 392 | 402 | 421 | 442 | 440 |
| Poland: | | | | | |
| Rock salt | 1,447 | 1,475 | 1,247 | 1,306 | [e]1,321 |
| Other salt | 3,261 | 2,776 | [e]2,750 | 3,337 | [e]4,000 |
| Portugal: | | | | | |
| Rock salt | 450 | 448 | 467 | 502 | 510 |
| Marine salt[e] | 130 | 110 | 120 | [r]120 | 120 |
| Romania | 5,548 | 5,243 | 5,066 | [e]5,000 | 5,000 |
| Senegal | [e]155 | 176 | 190 | 182 | 180 |
| Sierra Leone[e] | 220 | 220 | 220 | 220 | 220 |
| Somalia[e] | 33 | 33 | 33 | 33 | 33 |
| South Africa, Republic of | 595 | 646 | 820 | 679 | [e]797 |
| Spain: | | | | | |
| Rock salt | 2,536 | 2,439 | 2,214 | 2,377 | 2,300 |
| Marine salt and other evaporated salt | 1,536 | 1,187 | 1,267 | 1,359 | 1,300 |
| Sri Lanka | 115 | 194 | 142 | 118 | 120 |
| Sudan | 71 | 31 | [e]80 | [e]80 | 80 |
| Switzerland | 475 | 399 | 349 | 410 | 420 |
| Syria | [e]100 | 112 | 96 | 96 | 100 |
| Taiwan | 387 | 289 | 87 | 241 | 190 |
| Tanzania | [e]41 | [e]41 | 31 | 24 | 20 |
| Thailand: | | | | | |
| Rock salt | 12 | 12 | 6 | 11 | 11 |
| Other salt[e] | 180 | 180 | 180 | 180 | 180 |
| Togo[e] | 1 | (4) | -- | -- | -- |
| Tunisia | 515 | 464 | 413 | 364 | [e]446 |
| Turkey | 1,539 | 1,448 | [e]1,540 | 1,432 | 1,400 |
| Uganda[e] | 6 | 6 | 6 | 6 | 6 |
| U.S.S.R | 16,755 | 17,416 | 17,857 | 18,200 | 18,700 |
| United Kingdom: | | | | | |
| Rock salt | 1,488 | 2,435 | 1,451 | 1,730 | 1,800 |
| Brine salt[10] | 1,603 | 1,713 | 1,537 | 1,569 | 1,700 |
| Other salt[10] | 4,317 | 4,270 | 3,969 | 4,557 | 4,500 |
| United States including Puerto Rico (sold or used by producers): | | | | | |
| Rock salt | 11,871 | 13,508 | 9,941 | 13,355 | [e]14,060 |
| Other salt: | | | | | |
| United States | 27,086 | 24,391 | 24,632 | 25,871 | [e]24,815 |
| Puerto Rico[e] | 8 | 16 | 32 | 30 | 35 |
| Venezuela | [e]275 | 375 | 342 | [r] [e]360 | 390 |
| Vietnam[e] | 445 | 720 | 960 | 880 | 880 |
| Yemen (Aden)[e] | 80 | 80 | 80 | 80 | 80 |
| Yemen (Sanaa)[e] | [r]70 | 60 | 155 | 160 | 180 |
| Yugoslavia: | | | | | |
| Rock salt | 212 | 219 | 212 | | |
| Marine salt | 40 | 42 | 32 | 419 | [e]450 |
| Salt from brine | 209 | 211 | 215 | | |
| Total | [r]188,953 | [r]180,320 | 175,434 | 183,699 | 187,698 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Table includes data available through June 24, 1986.

[2]Salt is produced in many other countries, but quantities are relatively insignificant and reliable production data are not available.

[3]Year ending June 30 of that stated.

[4]Less than 1/2 unit.

[5]Data represent sales.

[6]Reported figure.

[7]Brine salt production as reported by the Burmese Government was as follows, in short tons: 1981—92,368; 1982—81,462; 1983—221,502; 1984—89,470; and 1985—49,061.

[8]Year beginning Mar. 21 of that stated.

[9]Fiscal year ending Mar. 31 of that stated.

[10]Data captioned "Brine salt" for the United Kingdom are the quantities of salt obtained from the evaporation of brines; that captioned "Other salt" are the salt content of brines used for purposes other than production of salt by evaporation.

# Sand and Gravel

## By Valentin V. Tepordei[1]

A total of 800 million short tons of construction sand and gravel valued at $2.4 billion, f.o.b. plant, was estimated to have been produced in the United States in 1985. This tonnage is the highest production reported since 1979, and 17% below the record high production of 1978, but 3% higher than that of 1984, when the last full annual survey was conducted.

Production of industrial sand and gravel in 1985 was unchanged from that of 1984 and totaled 29.4 million tons valued at $374 million, f.o.b. plant, a 12% decrease from the record high production of 1979.

Exports of construction sand and gravel in 1985 decreased 18% to 1.5 million tons valued at $8.9 million, while imports increased 63% to 246,000 tons valued at $1.6 million. Domestic apparent consumption of construction sand and gravel in 1985 was 799 million tons.

Exports of industrial sand decreased 27% in 1985 to 866,000 tons valued at $22.6 million, while imports for consumption increased 212% to 81,000 tons valued at $1.5 million. Domestic apparent consumption of industrial sand and gravel was 28.6 million tons.

**Table 1.—Salient U.S. sand and gravel statistics[1]**

(Thousand short tons and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Sold or used: | | | | | |
| Construction sand and gravel: | | | | | |
| Quantity | [e]690,000 | 594,000 | [e]655,100 | 773,900 | [e]800,100 |
| Value | [e]$1,928,000 | $1,674,000 | [e]$1,935,000 | $2,244,000 | [e]$2,438,000 |
| Industrial: | | | | | |
| Sand: | | | | | |
| Quantity | 29,250 | 26,350 | 26,080 | 28,680 | 29,070 |
| Value | $326,300 | $316,900 | $329,500 | $370,370 | $370,730 |
| Gravel: | | | | | |
| Quantity | 728 | 1,024 | 537 | 705 | 357 |
| Value | $5,997 | $6,846 | $5,667 | $6,844 | $3,340 |
| Total industrial:[2] | | | | | |
| Quantity | 29,980 | 27,400 | 26,620 | 29,380 | 29,430 |
| Value | $332,300 | $323,800 | $335,200 | $377,200 | $374,070 |
| Exports: | | | | | |
| Quantity | 2,397 | 1,946 | 2,350 | 3,038 | 2,379 |
| Value | $36,736 | $34,397 | $32,487 | $37,981 | $31,515 |
| Imports for consumption: | | | | | |
| Quantity | 337 | 275 | 181 | 177 | 327 |
| Value | $2,608 | $4,002 | $2,666 | $2,529 | $3,085 |

[e] Estimated.

[1] Puerto Rico excluded from all sand and gravel statistics.

[2] Data may not add to totals shown because of independent rounding.

**Domestic Data Coverage.**—Domestic production data for construction and industrial sand and gravel are developed by the Bureau of Mines from voluntary surveys of U.S. producers. Beginning with 1981, full surveys of construction sand and gravel producers are conducted for even-numbered years only. For odd-numbered years, preliminary surveys are conducted that collect production information on a sample basis that is used to generate only annual preliminary estimates at the State level. Industrial sand and gravel producers are surveyed every year. Of the 181 industrial sand and gravel operations surveyed, 139, or 76%, reported to the Bureau of Mines. Of these, 136 operations were active and their total production was 24.5 million tons, or 83% of the U.S. total industrial sand and gravel produced. The nonrespondents' production was estimated using production reports, adjusted prior years' production, and/or employment data. Of the 139 reporting operations, 18 did not indicate a breakdown by end uses. Their total production, as well as that of the 32 estimated operations representing 17% of the U.S. total, was included in "other unspecified uses." In 1985, 13 industrial sand and gravel operations were idle.

**Legislation and Government Programs.**—On March 5, the U.S. Congress approved an 18-month Interstate Cost Estimate (ICE) legislation that retroactively gave the U.S. Department of Transportation the authority to disburse to the States construction funds collected into the Federal Highway Trust Fund for the period ending September 30, 1985. On September 19, an additional ICE legislation was passed by the U.S. Congress for the period ending September 30, 1986. Most of these funds were to be used for highway construction and repair work, and their late release impacted to some extent the demand for construction sand and gravel.

In August 1985, the Environmental Protection Agency issued its final regulations establishing particulate emission standards of performance for nonmetallic mineral processing plants. The regulations went into effect on August 1, and will be implemented under section 111 of the Clean Air Act. The standards were based on emission levels achievable using well-designed and operated baghouse controls or wet-dust suppression techniques. The standards apply to new, modified, and reconstructed facilities at plants processing 18 industrial minerals including sand and gravel.

## CONSTRUCTION SAND AND GRAVEL

### DOMESTIC PRODUCTION

Revised production estimates indicate that in 1985 U.S. output of construction sand and gravel increased 3% compared with that of 1984. All regions, except New England and West South Central, registered increases up to 11%. The Pacific region continued to lead the Nation with an estimated 178 million tons, or 22% of the U.S. total, followed by the East North Central region with 132 million tons, or 17% of the total, and the Mountain region with 113 million tons, or 14% of the total.

Among the four major geographic regions, the West again led the Nation in the production of construction sand and gravel with 36% of the total. The North Central region was next with 27%, and the South was third with 25%. Construction sand and gravel was produced in every State, and the 10 leading States, in descending order of volume, were California, Texas, Michigan, Arizona, Ohio, Alaska, New York, Colorado, Illinois, and Minnesota. Their combined estimated production represented 52% of the national total.

Tarmac PLC of Wolverhampton, United Kingdom, purchased the Florida aggregates and ready-mix concrete operations of Lone Star Industries Inc. of Fort Lauderdale, FL. The newly formed company, Tarmac Florida Inc., will be situated in Fort Lauderdale, FL. Pioneer Concrete of Texas Inc., based in Houston, TX, purchased four sand and gravel operations and seven ready-mix concrete plants in south Texas from Lone Star Industries. A Hawaiian affiliate of Lone Star Industries formed a partnership with Adelaide Brighton Cement Holdings Ltd. of Australia and purchased Lone Star's aggregate and ready-mix concrete operations throughout Hawaii.

River Aggregates Co. of Hernando, MS, a subsidiary of River Cement Co. of Orange, TX, is a new major sand and gravel producer in Mississippi. A long-time cement supplier of this area, River Cement decided to diversify by becoming a sand and gravel producer. The new operation, near the Mississippi-Tennessee border, is equipped with a 600-ton-per-hour processing plant.

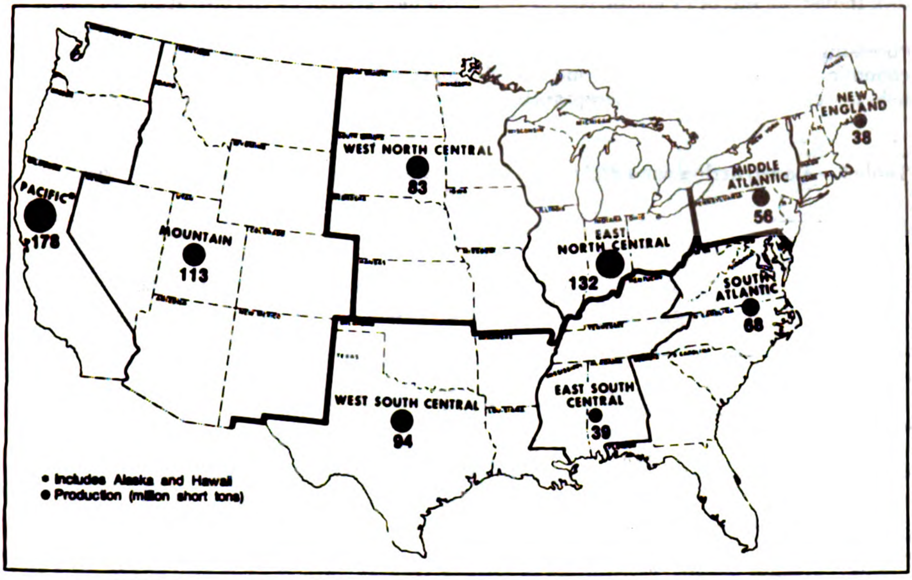

Figure 1.—Production of construction sand and gravel in the United States in 1985, by geographic region.

## FOREIGN TRADE

**Exports.**—Exports of construction sand decreased 18% to 997,000 tons valued at $6.2 million. Canada was the major destination, receiving 90% of the total, while Mexico received 7%. Exports of construction gravel decreased 19% to 516,000 tons valued at $2.7 million, 94% of which went to Canada.

**Imports.**—Imports for consumption of construction sand and gravel increased 63% to 246,000 tons valued at $1.6 million, 86% of which came from Canada.

## TECHNOLOGY

The National Sand and Gravel Association's Annual Plant Operator's Forum, held in Los Angeles, CA, from March 17 to March 20, 1985, covered a broad range of topics related to the use of hydraulic dredging in sand and gravel operations. Automation of sand and gravel plants, computer-controlled sand classifiers, and tips on how to design portable plants for easy relocation within the pit were also discussed.[2] A review of the basics of hydraulic dredging technology and how it can help a sand and gravel operation grow and increase profitability was published by a leading expert in this field.[3]

A computer-controlled sand classifier installed by Eastern Aggregates Inc. of Davidsonville, MD, was instrumental in increasing concrete sand production at the plant. The computerized classifier tracks raw material fed into the system, calculates the optimal settings for different discharge stations, and transmits the parameters to the central control station. Based on the automatic readouts of the sand's fineness modulus made every 6 minutes, the system adjusts the yield from the varying feed stocks to meet preset specifications.[4]

Midwestern Industries of Massillon, OH, introduced a new screening system called Multi-Vib. The system stratifies the material in a shallow fluidized bed on each deck with rapid drop-through of particles. The process reduces the wear of the screens and sizes the material more accurately into the final products.[5]

The chances of success in obtaining mining permits are significantly improved if long-range mining plans of aggregate producing operations are properly presented to the public. Three-dimensional quarry models displaying the present and the future of the operation were successfully used by Cooley Gravel Co. of Denver, CO, and Trap

Rock Industries Inc. of Franklin, NJ.[6]

The decision to automate an aggregate processing plant is usually determined by economic factors. However, the success of such an effort depends on acceptance of the new system by the operating personnel, according to an article that reviewed the human and economic aspects of plant automation.[7]

### Table 2.—Construction sand and gravel sold or used in the United States, by geographic region

| Geographic region | 1984 |  |  |  | 1985 |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  | Quantity (thousand short tons) | Percent of total | Value (thousands) | Percent of total | Quantity[e] (thousand short tons) | Percent of total | Value[e] (thousands) | Percent of total |
| Northeast: |  |  |  |  |  |  |  |  |
| New England | 39,694 | 5 | $113,590 | 5 | 38,300 | 5 | $117,900 | 5 |
| Middle Atlantic | 49,985 | 6 | 177,028 | 8 | 55,600 | 7 | 199,200 | 8 |
| North Central: |  |  |  |  |  |  |  |  |
| East North Central | 127,643 | 17 | 336,715 | 15 | 132,200 | 17 | 370,800 | 16 |
| West North Central | 80,307 | 10 | 183,146 | 8 | 82,600 | 10 | 196,400 | 8 |
| South: |  |  |  |  |  |  |  |  |
| South Atlantic | 63,609 | 8 | 187,397 | 8 | 67,900 | 8 | 203,400 | 8 |
| East South Central | 36,697 | 5 | 99,225 | 4 | 39,200 | 5 | 115,000 | 5 |
| West South Central | 98,748 | 13 | 304,493 | 14 | 93,900 | 12 | 302,700 | 12 |
| West: |  |  |  |  |  |  |  |  |
| Mountain | 107,332 | 14 | 314,833 | 14 | 112,900 | 14 | 338,400 | 14 |
| Pacific | 169,861 | 22 | 527,528 | 24 | 177,500 | 22 | 594,200 | 24 |
| Total[1] | 773,900 | 100 | 2,244,000 | 100 | 800,100 | 100 | 2,438,000 | 100 |

[e] Estimated.

[1] Data may not add to totals shown because of independent rounding.

### Table 3.—Construction sand and gravel sold or used in the United States, by State

(Thousand short tons and thousand dollars)

| State | 1984 |  | 1985[e] |  |
|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value |
| Alabama | 10,348 | 26,188 | 11,000 | 32,000 |
| Alaska | 30,861 | 66,883 | 29,000 | 63,000 |
| Arizona | 30,439 | 101,959 | 37,000 | 118,000 |
| Arkansas | 8,334 | 23,786 | 8,500 | 24,400 |
| California | 102,420 | 360,427 | 112,800 | 430,000 |
| Colorado | 28,024 | 87,324 | 27,500 | 88,000 |
| Connecticut | 6,718 | 22,817 | 6,000 | 21,000 |
| Delaware | 1,003 | 2,795 | 1,300 | 4,000 |
| Florida | 21,032 | 48,494 | 22,500 | 49,500 |
| Georgia | 5,347 | 13,623 | 5,000 | 13,400 |
| Hawaii | 436 | 2,031 | 500 | 2,100 |
| Idaho | 4,725 | 13,509 | 4,000 | 11,400 |
| Illinois | 25,969 | 72,477 | 26,600 | 77,000 |
| Indiana | 16,071 | 44,744 | 18,600 | 55,800 |
| Iowa | 13,882 | 37,027 | 12,000 | 30,500 |
| Kansas | 11,796 | 26,358 | 13,200 | 31,800 |
| Kentucky | 7,839 | 18,252 | 7,600 | 19,000 |
| Louisiana | 17,040 | 54,664 | 15,000 | 48,000 |
| Maine | 7,885 | 19,228 | 7,200 | 18,000 |
| Maryland | 14,234 | 46,671 | 17,000 | 58,000 |
| Massachusetts | 14,168 | 42,139 | 14,900 | 47,500 |
| Michigan | 36,071 | 76,540 | 38,000 | 93,000 |
| Minnesota | 22,612 | 49,087 | 25,000 | 55,500 |
| Mississippi | 12,205 | 34,955 | 13,400 | 42,000 |
| Missouri | 7,967 | 19,364 | 7,500 | 20,000 |
| Montana | 7,776 | 21,269 | 9,000 | 26,000 |
| Nebraska | 11,839 | 27,791 | 11,600 | 28,800 |
| Nevada | 8,202 | 20,505 | 9,500 | 24,800 |
| New Hampshire | 5,637 | 16,054 | 6,300 | 19,800 |
| New Jersey | 9,545 | 31,878 | 10,600 | 36,700 |
| New Mexico | 8,363 | 22,389 | 8,400 | 22,800 |
| New York | 25,968 | 80,866 | 28,000 | 88,500 |
| North Carolina | 6,312 | 18,159 | 6,100 | 19,500 |
| North Dakota | 6,426 | 11,351 | 6,900 | 13,800 |
| Ohio | 31,748 | 104,709 | 33,000 | 109,000 |
| Oklahoma | 10,984 | 26,582 | 12,600 | 32,300 |
| Oregon | 12,776 | 37,117 | 12,500 | 36,800 |
| Pennsylvania | 14,472 | 64,285 | 17,000 | 74,000 |

See footnotes at end of table.

## Table 3.—Construction sand and gravel sold or used in the United States, by State —Continued

(Thousand short tons and thousand dollars)

| State | 1984 | | 1985[e] | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Rhode Island | 1,483 | 5,282 | 1,200 | 4,600 |
| South Carolina | 5,845 | 17,097 | 4,900 | 14,000 |
| South Dakota | 5,786 | 12,168 | 6,400 | 16,000 |
| Tennessee | 6,304 | 19,830 | 7,200 | 22,000 |
| Texas | 62,389 | 199,461 | 57,800 | 198,000 |
| Utah | 15,217 | 34,507 | 14,000 | 36,400 |
| Vermont | 3,802 | 8,071 | 2,700 | 7,000 |
| Virginia | 8,860 | 37,359 | 10,200 | 42,000 |
| Washington | 23,369 | 61,070 | 22,700 | 62,300 |
| West Virginia | 976 | 3,198 | 900 | 3,000 |
| Wisconsin | 17,785 | 38,245 | 16,000 | 36,000 |
| Wyoming | 4,586 | 13,372 | 3,500 | 11,000 |
| Total[1] | 773,900 | 2,244,000 | 800,100 | 2,438,000 |

[e]Estimated.

[1]Data may not add to totals shown because of independent rounding.

## Table 4.—U.S. exports of construction sand and gravel, by country

(Thousand short tons and thousand dollars)

| Country | Construction sand | | Gravel | |
|---|---|---|---|---|
| | Quantity | F.a.s. value[1] | Quantity | F.a.s. value[1] |
| **1984** | | | | |
| Bahamas | (2) | 3 | 1 | 16 |
| Canada | 1,006 | 3,215 | 616 | 1,635 |
| Mexico | 181 | 1,534 | 1 | 20 |
| Other | 23 | 3,342 | 17 | 560 |
| Total | 1,210 | 8,094 | 635 | 2,231 |
| **1985** | | | | |
| Canada | 892 | 3,061 | 485 | 1,430 |
| Germany, Federal Republic of | 4 | 657 | -- | -- |
| Mexico | 74 | 520 | 11 | 238 |
| Netherlands Antilles | 1 | 7 | 8 | 131 |
| Saudi Arabia | 11 | 64 | (2) | 7 |
| Trinidad and Tobago | 4 | 244 | 1 | 112 |
| Other | 11 | 1,659 | 11 | 806 |
| Total | 997 | 6,212 | 516 | [3]2,723 |

[1]Value of material at U.S. port of export; based on transaction price, including all charges incurred in placing material alongside ship.

[2]Less than 1/2 unit.

[3]Data do not add to total shown because of independent rounding.

## Table 5.—U.S. imports for consumption of construction sand and gravel, by country

(Thousand short tons and thousand dollars)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | C.i.f. value[1] | Quantity | C.i.f. value[1] |
| Antigua | 3 | 23 | 9 | 61 |
| Bahamas | 14 | 110 | -- | -- |
| British Virgin Islands | 4 | 82 | 11 | 155 |
| Canada | 121 | 1,100 | 212 | 908 |
| Mexico | -- | 2 | 2 | 20 |
| Spain | -- | -- | 11 | 297 |
| Other | [r]9 | [r]287 | 1 | 131 |
| Total | 151 | [2]1,603 | 246 | 1,572 |

[r]Revised.

[1]Value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.

[2]Data do not add to total shown because of independent rounding.

# INDUSTRIAL SAND AND GRAVEL

## DOMESTIC PRODUCTION

The total output of industrial sand and gravel in 1985 was 29.4 million tons, unchanged from that of 1984. The North Central region continued to lead the Nation with 40% of the U.S. total, followed by the South with 36%, the Northeast with 13%, and the West with 11%. Compared with that of 1984, the output of industrial sand and gravel by region increased 3.6% in the South and slightly in the Northeast, and decreased 3.9% in the West and slightly in the North Central region.

Based on the 1980 census data on population, U.S. per capita industrial sand and gravel production was 0.13 ton. Per capita production by region was 0.20 ton in the North Central, followed by the South with 0.14 ton, and the West and the Northeast with 0.08 ton.

The 10 leading States in the production of industrial sand and gravel in 1985 were, in descending order of volume, Illinois, Michigan, New Jersey, California, Florida, Texas, Ohio, North Carolina, Wisconsin, and Oklahoma. Their combined production represented 73% of the national total. Production increased 38% in Florida, 13% in Wisconsin, 12% in North Carolina, and 4% in New Jersey, but decreased 13% in Ohio and slightly in California and Illinois.

In 1985, 98 producers of industrial sand and gravel with 169 active operations were canvassed by the Bureau of Mines. About 75% of the industrial sand and gravel produced came from 49 operations, each with an annual production of more than 200,000 tons. The 10 leading producers of industrial sand and gravel were, in descending order of tonnage, Unimin Corp., Pennsylvania Glass Sand Corp. (PGS), The Morie Co. Inc., Ottawa Silica Co., Manley Bros. of Indiana Inc., Standard Sand & Silica Co., Oglebay Norton Co., Construction Aggregates Corp., Wedron Silica Co., and Badger Mining Corp. Their combined production, from 54 operations, represented 67% of the U.S. total.

PGS of Berkley Springs, WV, the second largest U.S. producer of industrial sand, was sold in the second half of 1985 by its parent company, International Telephone & Telegraph Corp. of New York, NY, to United States Borax & Chemical Corp. of Los Angeles, CA, a subsidiary of The Rio Tinto-Zinc Corp. PLC of London, United Kingdom. The sale followed expansion plans announced by PGS in 1984 that included the installation of new automated production and quality control equipment, and automated packaging and shipping facilities at four of its operations.

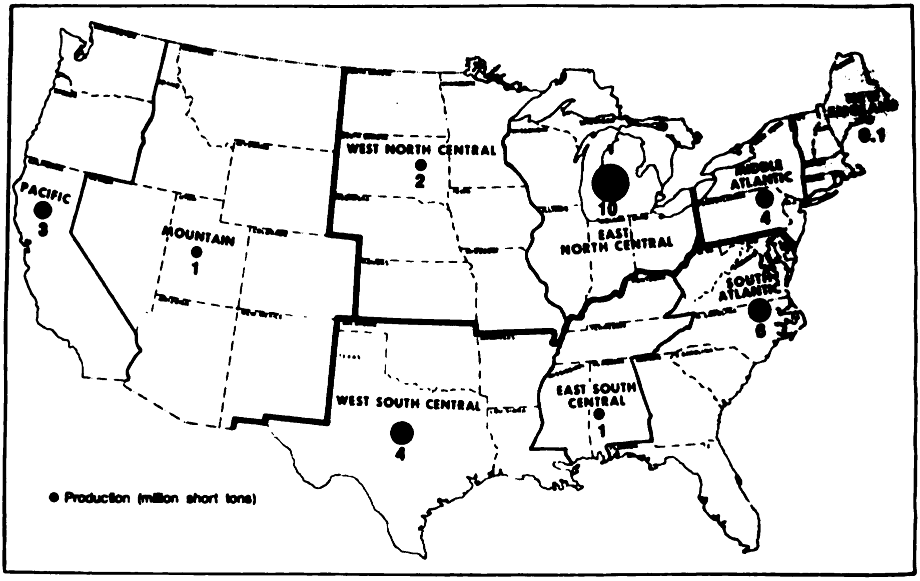

Figure 2.—Production of industrial sand and gravel in the United States in 1985, by geographic region.

## CONSUMPTION AND USES

Sand and gravel production reported by producers to the Bureau of Mines is actually material sold or used by the companies. Stockpiled material is not reported until it is consumed.

Of the 29.1 million tons of industrial sand sold or used, 35% was consumed as glassmaking sand and 18% as foundry sand. Other important uses were hydraulic fracturing sand with 7%, and abrasive sand with 6%. Because some companies did not report a breakdown by end use, their total production as well as the estimates for nonrespondents were included in "Other unspecified uses," which represent about 19% of total U.S. output. On a regional level, most of the glassmaking sand was produced in the South, 39%, followed by the North Central, 26%, and the West, 18%; while most of the foundry sand was produced in the North Central, 67%, and the South, 17%. Of the smaller by volume but important uses, most of the hydraulic fracturing sand was produced in the North Central, 66%, and the South, 31%; while most of the abrasive sand was produced in the South, 53%.

## PRICES

The average value, f.o.b. plant, of U.S. industrial sand and gravel decreased slightly to $12.71 per ton. Average unit values for industrial sand and industrial gravel were $12.75 and $9.36 per ton, respectively. Nationally, silica sand used as fillers in rubber and paint had the highest value per ton, $53.72; followed by silica sand used in ceramics, $35.30; fiberglass ground, $27.28; and silica flour, $25.81.

## TRANSPORTATION

Of the total industrial sand and gravel produced, 80% was transported by truck from the plant to the site of first point of sale or use, 18% by rail, and less than 1% by waterway. Because most of the producers had no records of and/or did not report shipping distances or cost per ton per mile, no transportation cost data were available.

## FOREIGN TRADE

**Exports.**—Exports of industrial sand decreased 27% to 866,000 tons valued at $22.6 million. Of this, 85% went to Canada, and 6% went to Mexico.

**Imports.**—Imports of for consumption industrial sand increased 212% to 81,000 tons valued at $1.5 million. Of this, 52% came from Australia, 17% from Antigua, and 14% from Japan.

## TECHNOLOGY

A consortium of seven companies was established to sponsor research and development in glass technology. The companies involved in this joint venture were ACI International Ltd. of Melbourne, Australia; Brockway Inc. of Brockway, PA; Consumers Glass Co. Ltd. of Toronto, Canada; Emhart Corp. of Farmington, CT; Rockware Glass of Windsor Berks, United Kingdom; Weingand Glass of the Federal Republic of Germany; and Yamamura Glass of Japan. A total of $5 million over a 3-year period will be provided by the group to fund seven research projects. The aim of the research is to develop a strong, lightweight, glass container that could successfully compete with plastic containers. The first phase of the project, conducted at selected research institutes and organizations addressed the development of new glass technology. The second phase of the project will involve the assessment of economic and practical factors of implementing the new technology. Proposed research includes a project at the Massachusetts Institute of Technology that will examine the use of special coatings on glass containers.[8]

Within the next 1 or 2 years, a 16-ounce-capacity super-lightweight nonrefillable soft drink glass container will be manufactured in the United States. The weight of this new container was estimated to be 5 ounces, which is approximately 36% less than the present weight level for this type of container. The weight-to-capacity ratio of about 0.3 for the new container also represents a significant reduction from present levels.[9]

Recent advances in microcomputer hardware and software provided the capability of performing complex batch calculations on inexpensive desk-top models. A microcomputer program was developed at Rutgers University, Department of Ceramic Engineering, which enables optimum glass batch formulation using Linear programming techniques (LP). Previously, such applications required the use of more expensive large mainframe computers. The LP procedure improved the accuracy of glass batch formulation, especially when complex raw materials are used, provided the capability of easily establishing tolerance limits for each oxide level, and controlled many key glass batch parameters in a single integrated computation.[10]

The recent advances achieved in high-intensity wet and dry magnetic separation techniques extended their usefulness for processing industrial minerals. Such new developments included the use of strong rare-earth permanent magnetic separators, large-particle-size electromagnetic separators, and superconducting cryogenic wet and dry systems. Several systems capable of separating minerals on the basis of their magnetic repelling properties rather than their attracting properties also were studied.[11]

The Western Australian government introduced a computerized information system that allowed instant access to the results of mineral exploration performed previously by mining companies. Under the provisions of the Mining Act, companies are required to report all technical details of their exploration activities to the Department of Mines. These reports become eligible for open-file release when the exploration tenements are relinquished. By having access to such reports, companies interested in new exploration will be able to review previous exploration programs and avoid costly duplication.[12]

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[1] Physical scientist, Division of Industrial Minerals.

[2] Robertson, J. L. Dredging Tops NSGA Program. Rock Prod., v. 88, No. 6, June 1985, pp. 36-38.

[3] Turner, T. M. Is Dredging in Your Future? Rock Prod., v. 88, No. 11, Nov. 1985, pp. 27-31.

[4] Robertson, J. L. Computer Raises Sand Production. Rock Prod., v. 88, No. 9, Sept. 1985, pp. 47-49.

[5] Pit & Quarry. Vertical Sizing Screening Produces Consistent Specs. V. 77, No. 12, June 1985, pp. 40-41.

[6] Rukavina, M. Quarry Model Is Reclamation Aid. Rock Prod., v. 88, No. 5, May 1985, pp. 44-45, 65.

[7] Michard, D. Plant Automation: Human & Economic Aspects. Pit & Quarry, v. 78, No. 5, Nov. 1985, pp. 27-29.

[8] Industrial Minerals (London). International Glass Research. No. 211, Apr. 1985, p. 15.

[9] Southwick, R. D. A Super-Lightweight Container Is Feasible. Glass Ind., v. 66, No. 7, June 10, 1985, pp. 14-17.

[10] Lehman, R. L. Microcomputers Can Be Used To Optimize Batch Formulation. Glass Ind., v. 66, No. 8, July 1985, pp. 14-17.

[11] Clark, G. Magnetic Separation. Ind. Miner. (London), No. 212, May 1985, pp. 21-33.

[12] Industrial Minerals (London). Mines Department Launches First Computerized Database. No. 214, July 1985, p. 9.

### Table 6.—Industrial sand and gravel sold or used in the United States, by geographic region

| Geographic region | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Quantity (thousand short tons) | Percent of total | Value (thousands) | Percent of total | Quantity (thousand short tons) | Percent of total | Value (thousands) | Percent of total |
| Northeast: | | | | | | | | |
| New England | 186 | 1 | $3,781 | 1 | 164 | 1 | $3,879 | 1 |
| Middle Atlantic | 3,459 | 12 | 43,725 | 12 | 3,542 | 12 | 41,352 | 11 |
| North Central: | | | | | | | | |
| East North Central | 10,260 | 35 | 119,035 | 31 | 10,092 | 34 | 120,162 | 32 |
| West North Central | 1,668 | 5 | 25,988 | 7 | 1,578 | 5 | 25,523 | 7 |
| South: | | | | | | | | |
| South Atlantic | 5,348 | 18 | 65,126 | 17 | 5,959 | 20 | 67,060 | 18 |
| East South Central | 1,128 | 4 | 10,939 | 3 | 1,121 | 4 | 11,113 | 3 |
| West South Central | 3,881 | 13 | 52,655 | 14 | 3,648 | 12 | 52,004 | 14 |
| West: | | | | | | | | |
| Mountain | 819 | 3 | 11,595 | 3 | 746 | 3 | 9,950 | 3 |
| Pacific | 2,638 | 9 | 44,377 | 12 | 2,576 | 9 | 43,022 | 11 |
| Total[1] | 29,380 | 100 | 377,200 | 100 | 29,430 | 100 | 374,070 | 100 |

[1] Data may not add to totals shown because of independent rounding.

### Table 7.—Industrial sand and gravel sold or used in the United States, by State

(Thousand short tons and thousand dollars)

| State | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Alabama | 442 | 3,600 | 524 | 4,533 |
| Arizona | W | W | W | W |
| Arkansas | 459 | 6,207 | 412 | 5,414 |
| California | 2,281 | 39,176 | 2,255 | 37,434 |
| Colorado | 149 | 2,218 | W | W |
| Connecticut | W | W | W | W |
| Florida | 1,533 | 9,815 | 2,123 | 12,642 |
| Georgia | 478 | 6,795 | 571 | 6,675 |

See footnotes at end of table.

## Table 7.—Industrial sand and gravel sold or used in the United States, by State —Continued

(Thousand short tons and thousand dollars)

| State | 1984 Quantity | 1984 Value | 1985 Quantity | 1985 Value |
|---|---|---|---|---|
| Idaho | W | W | W | W |
| Illinois | 4,100 | 52,197 | 4,056 | 56,915 |
| Indiana | 194 | 1,129 | 182 | 1,209 |
| Kansas | W | W | 134 | 1,124 |
| Kentucky | W | W | W | W |
| Louisiana | 266 | 3,757 | 267 | 3,838 |
| Maryland | W | W | W | W |
| Massachusetts | W | W | W | W |
| Michigan | 3,400 | 33,060 | 3,345 | 25,469 |
| Minnesota | W | W | 884 | 16,910 |
| Mississippi | W | W | W | W |
| Missouri | 614 | 8,129 | 535 | 7,330 |
| Montana | W | W | W | W |
| Nebraska | W | W | W | W |
| Nevada | 489 | W | 479 | 5,944 |
| New Jersey | 2,712 | 32,287 | 2,820 | 31,119 |
| New York | 25 | 260 | W | W |
| North Carolina | 1,158 | 12,864 | 1,294 | 13,086 |
| Ohio | 1,506 | 20,829 | 1,312 | 21,945 |
| Oklahoma | W | W | W | W |
| Pennsylvania | W | W | 693 | 9,846 |
| Rhode Island | W | W | W | W |
| South Carolina | 882 | 14,889 | 794 | 14,092 |
| Tennessee | 650 | 6,903 | 569 | 6,156 |
| Texas | 2,028 | 29,282 | 1,968 | 29,095 |
| Utah | 11 | W | 8 | 144 |
| Virginia | W | W | W | W |
| Washington | 356 | 5,201 | 322 | 5,589 |
| West Virginia | W | W | W | W |
| Wisconsin | 1,060 | 11,821 | 1,197 | 14,624 |
| Other | 4,587 | 76,803 | 2,686 | 42,934 |
| Total[1] | 29,380 | 377,200 | 29,430 | 374,070 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Data may not add to totals shown because of independent rounding.

## Table 8.—Industrial sand and gravel production in the United States in 1985, by size of operation

| Size range | Number of operations | Percent of total | Quantity (thousand short tons) | Percent of total |
|---|---|---|---|---|
| Less than 25,000 | 35 | 20.7 | 288 | 1.0 |
| 25,000 to 49,999 | 33 | 19.5 | 1,166 | 4.0 |
| 50,000 to 99,999 | 23 | 13.6 | 1,796 | 6.1 |
| 100,000 to 199,999 | 29 | 17.2 | 4,038 | 13.7 |
| 200,000 to 299,999 | 11 | 6.5 | 2,753 | 9.4 |
| 300,000 to 399,999 | 14 | 8.3 | 4,764 | 16.2 |
| 400,000 to 499,999 | 9 | 5.3 | 3,991 | 13.6 |
| 500,000 to 599,999 | 2 | 1.2 | 1,041 | 3.5 |
| 600,000 to 699,999 | 4 | 2.4 | 2,572 | 8.7 |
| 700,000 to 799,999 | 7 | 4.1 | 5,132 | 17.4 |
| 800,000 and over | 2 | 1.2 | 1,885 | 6.4 |
| Total | 169 | 100.0 | [1]29,430 | 100.0 |

[1] Data do not add to total shown because of independent rounding.

## Table 9.—Number of industrial sand and gravel operations and processing plants in the United States in 1985, by geographic region

| Geographic region | Mining operations on land | | | | Dredging operations | Total active operations |
|---|---|---|---|---|---|---|
| | Stationary | Portable | Stationary and portable | No plants or unspecified | | |
| Northeast: | | | | | | |
| New England | 4 | -- | -- | 1 | 1 | 5 |
| Middle Atlantic | 14 | -- | -- | 5 | 5 | 19 |
| North Central: | | | | | | |
| East North Central | 37 | 1 | -- | 2 | 2 | 40 |
| West North Central | 10 | -- | -- | -- | 3 | 10 |
| South: | | | | | | |
| South Atlantic | 20 | 3 | 1 | 6 | 8 | 30 |
| East South Central | 10 | 2 | 1 | 4 | 3 | 17 |
| West South Central | 21 | 1 | -- | 3 | 7 | 25 |
| West: | | | | | | |
| Mountain | 7 | -- | -- | 2 | 1 | 9 |
| Pacific | 12 | -- | -- | 2 | 3 | 14 |
| Total | 135 | 7 | 2 | 25 | 33 | 169 |

## Table 10.—Industrial sand and gravel sold or used by U.S. producers, by major use

| Major use | Northeast | | | North Central | | | South | | | West | | | U.S. total[1] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity (thousand short tons) | Value (thousands) | Value per ton | Quantity (thousand short tons) | Value (thousands) | Value per ton | Quantity (thousand short tons) | Value (thousands) | Value per ton | Quantity (thousand short tons) | Value (thousands) | Value per ton | Quantity (thousand short tons) | Value (thousands) | Value per ton |
| 1984 | | | | | | | | | | | | | | | |
| Sand: | | | | | | | | | | | | | | | |
| Glassmaking: | | | | | | | | | | | | | | | |
| Containers | 1,365 | $17,526 | $12.84 | 1,952 | $20,111 | $10.30 | 2,400 | $28,358 | $11.82 | 1,856 | $31,185 | $16.80 | 7,574 | $97,180 | $12.83 |
| Flat (plate and window) | W | W | 13.02 | 522 | 4,818 | 9.23 | 1,171 | 13,745 | 11.74 | W | W | 14.29 | 1,814 | 20,182 | 11.13 |
| Specialty | W | W | 14.07 | 414 | 5,173 | 12.50 | 268 | 3,061 | 11.42 | W | W | 26.00 | 867 | 10,849 | 12.51 |
| Fiberglass (unground) | W | W | 10.69 | 237 | 2,951 | 12.45 | W | W | 16.05 | W | W | 14.70 | 560 | 7,619 | 13.61 |
| Fiberglass (ground) | W | W | 40.00 | W | W | 29.50 | 492 | 10,607 | 21.56 | W | W | 26.50 | 526 | 11,678 | 22.20 |
| Foundry: | | | | | | | | | | | | | | | |
| Molding and core | 700 | 6,506 | 9.29 | 4,586 | 50,583 | 11.03 | 1,095 | 11,272 | 10.29 | 145 | 2,122 | 14.63 | 6,526 | 70,488 | 10.80 |
| Molding and core facings (ground) | W | W | 16.67 | 492 | 4,102 | 8.34 | -- | -- | -- | W | W | 8.00 | 502 | 4,261 | 8.49 |
| Refractory | W | W | 24.29 | 167 | 1,640 | 9.82 | W | W | 17.93 | W | W | 13.00 | 211 | 2,513 | 11.91 |
| Metallurgical: | | | | | | | | | | | | | | | |
| Silicon carbide | W | W | 21.50 | 132 | 1,323 | 10.02 | W | W | 60.00 | (2) | 4 | -- | 135 | 1,430 | 10.59 |
| Flux for metal smelting | -- | -- | -- | W | W | 4.10 | -- | -- | -- | W | W | 10.83 | 97 | 792 | 8.16 |
| Abrasives: | | | | | | | | | | | | | | | |
| Blasting | 206 | 3,824 | 18.56 | 389 | 8,862 | 22.78 | 907 | 14,588 | 16.08 | 308 | 3,826 | 12.42 | 1,810 | 31,099 | 17.18 |
| Scouring cleansers (ground) | W | W | W | 127 | 2,989 | 23.54 | W | W | 23.50 | W | W | 23.50 | 194 | 4,548 | 23.44 |
| Sawing and sanding | W | W | 10.73 | W | W | 19.67 | W | W | W | -- | -- | -- | 26 | 431 | 16.58 |
| Chemicals (ground and unground) | W | W | 12.60 | 222 | 2,441 | 11.00 | 128 | 1,901 | 14.85 | W | W | 14.00 | 425 | 5,308 | 12.48 |
| Fillers (ground): | | | | | | | | | | | | | | | |
| Rubber, paint, putty, etc | W | W | 24.00 | 42 | 723 | 17.21 | 58 | 1,002 | 17.28 | W | W | 18.90 | 122 | 2,153 | 17.65 |
| Ceramic (ground): | | | | | | | | | | | | | | | |
| Pottery, brick, tile, etc | W | W | 33.05 | 106 | 2,768 | 26.11 | W | W | 25.98 | W | W | 30.00 | 184 | 4,944 | 26.87 |
| Filtration | 22 | 969 | 44.05 | 75 | 751 | 10.01 | 99 | 769 | 7.77 | 21 | 240 | 11.43 | 217 | 2,729 | 12.58 |
| Traction (engine) | 26 | 271 | 10.42 | 122 | 1,171 | 9.60 | 55 | 515 | 9.36 | 43 | 522 | 12.14 | 246 | 2,479 | 10.08 |
| Coal washing | W | W | 11.50 | -- | -- | -- | W | W | 10.86 | -- | -- | -- | 25 | 274 | 10.96 |
| Roofing granules and fillers | 32 | 648 | 20.25 | 30 | 310 | 10.33 | 209 | 2,652 | 12.69 | 18 | 270 | 15.00 | 289 | 3,881 | 13.43 |
| Hydraulic fracturing | W | W | 11.00 | 1,246 | 24,261 | 19.47 | 767 | 12,608 | 16.44 | W | W | 22.05 | 2,057 | 37,806 | 18.38 |
| Silica flour | W | W | 61.07 | W | W | 90.06 | W | W | 78.46 | -- | -- | -- | 78 | 5,867 | 75.22 |
| Other uses, specified | 651 | 10,610 | 16.30 | 108 | 2,385 | 22.08 | 536 | 11,508 | 21.47 | 506 | 9,620 | 19.01 | XX | XX | XX |
| Other uses, unspecified[3] | 597 | 5,982 | 10.02 | 789 | 6,756 | 8.56 | 1,744 | 12,472 | 7.15 | 497 | 7,072 | 14.23 | 3,627 | 32,283 | 8.90 |
| Total[1] or average | 3,598 | 46,336 | 12.88 | 11,758 | 144,118 | 12.26 | 9,929 | 125,058 | 12.60 | 3,394 | 54,861 | 16.16 | 28,680 | 370,370 | 12.92 |

See footnotes at end of table.

## Table 10.—Industrial sand and gravel sold or used by U.S. producers, by major use —Continued

| Major use | Northeast | | | North Central | | | South | | | West | | | U.S. total[1] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity (thousand short tons) | Value (thousands) | Value per ton | Quantity (thousand short tons) | Value (thousands) | Value per ton | Quantity (thousand short tons) | Value (thousands) | Value per ton | Quantity (thousand short tons) | Value (thousands) | Value per ton | Quantity (thousand short tons) | Value (thousands) | Value per ton |
| 1984 —Continued | | | | | | | | | | | | | | | |
| Gravel: Metallurgical: | | | | | | | | | | | | | | | |
| Silicon, ferrosilicon | -- | -- | -- | -- | -- | -- | W | W | $6.55 | W | W | $17.28 | 198 | $1,715 | $8.66 |
| Filtration | W | W | $23.86 | 34 | $130 | $3.82 | W | W | 10.56 | W | W | 7.00 | W | W | 14.60 |
| Grinding | -- | -- | -- | W | W | 3.00 | -- | -- | -- | (2) | (2) | -- | W | W | 3.00 |
| Other uses | -- | -- | -- | W | W | 5.85 | 426 | $3,662 | 8.60 | W | W | 17.65 | 507 | 5,129 | 10.12 |
| Total[1] or average | W | W | 23.86 | 166 | 902 | 5.43 | 426 | 3,662 | 8.60 | W | W | 17.65 | 705 | 6,844 | 9.71 |
| Grand total[1] or average | W | W | 13.03 | 11,923 | 145,018 | 12.16 | 10,357 | 128,721 | 12.43 | W | W | 16.19 | 29,380 | 377,200 | 12.84 |
| 1985 | | | | | | | | | | | | | | | |
| Sand: | | | | | | | | | | | | | | | |
| Glassmaking: | | | | | | | | | | | | | | | |
| Containers | 1,369 | $17,538 | 12.81 | 1,562 | 19,663 | 12.59 | 2,235 | 26,996 | 12.08 | 1,656 | $27,133 | 16.38 | 6,822 | 91,330 | 13.39 |
| Flat (plate and window) | W | W | 12.41 | 448 | 4,319 | 9.64 | 1,138 | 12,860 | 11.30 | W | W | 14.48 | 1,777 | 19,815 | 11.15 |
| Specialty | W | W | 15.23 | 369 | 4,279 | 11.60 | W | W | 12.56 | -- | -- | -- | 768 | 9,790 | 12.75 |
| Fiberglass (unground) | W | W | 10.00 | 309 | 3,857 | 12.48 | W | W | 15.28 | 60 | 861 | 14.35 | 587 | 7,753 | 13.21 |
| Fiberglass (ground) | W | W | 58.00 | W | W | 30.68 | W | W | 27.26 | W | W | 21.71 | 339 | 9,247 | 27.28 |
| Foundry: | | | | | | | | | | | | | | | |
| Molding and core | 683 | 5,954 | 8.72 | 2,912 | 30,304 | 10.41 | 865 | 8,740 | 10.10 | 108 | 1,539 | 14.25 | 4,568 | 46,536 | 10.19 |
| Molding and core facing (ground) | W | W | 18.17 | W | W | 12.62 | -- | -- | -- | -- | -- | -- | 352 | 4,475 | 12.71 |
| Refractory | W | W | 24.71 | 184 | 1,677 | 9.11 | W | W | 17.88 | W | W | 17.82 | 223 | 2,457 | 11.02 |
| Metallurgical: | | | | | | | | | | | | | | | |
| Silicon carbide | W | W | 22.67 | W | W | 10.12 | 24 | 124 | 5.17 | 1 | W | 9 | 121 | 1,143 | 9.45 |
| Flux for metal smelting | -- | -- | -- | W | W | 7.57 | W | W | 13.50 | 51 | 619 | 12.14 | 67 | 753 | 11.24 |
| Abrasives: | | | | | | | | | | | | | | | |
| Blasting | 117 | 2,054 | 17.56 | 221 | 3,694 | 16.71 | 841 | 14,052 | 16.71 | 252 | 2,961 | 11.75 | 1,431 | 22,762 | 15.91 |
| Scouring cleansers (ground) | W | W | 28.00 | W | W | 21.94 | W | W | 26.12 | -- | -- | -- | 233 | 5,358 | 23.00 |
| Sawing and sanding | W | W | 13.00 | W | W | 20.27 | W | W | 25.00 | -- | -- | -- | 17 | 355 | 20.88 |
| Chemicals (ground and unground) | W | W | 12.42 | 125 | 1,355 | 10.84 | 176 | 2,613 | 14.85 | W | W | 19 | 378 | 4,924 | 13.03 |
| Fillers (ground): | | | | | | | | | | | | | | | |
| Rubber, paint, putty, etc | 21 | 1,341 | 63.86 | W | W | 95.33 | 96 | 4,768 | 49.67 | W | W | 18.38 | 137 | 7,360 | 53.72 |
| Silica flour | W | W | 26.63 | -- | -- | -- | W | W | 25.09 | -- | -- | -- | 21 | 542 | 25.81 |
| Ceramic (ground): | | | | | | | | | | | | | | | |
| Pottery, brick, tile, etc | W | W | 33.93 | W | W | 38.91 | 50 | 1,479 | 29.58 | -- | -- | -- | 150 | 5,295 | 35.30 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Filtration | 122 | 1,661 | 13.61 | 39 | 921 | 23.62 | 166 | 1,215 | 7.32 | 18 | 184 | 10.22 | 345 | 3,981 | 11.54 |
| Traction (engine) | 14 | 228 | 16.29 | 142 | 1,325 | 9.33 | 100 | 875 | 8.75 | 36 | 335 | 9.31 | 292 | 2,763 | 9.46 |
| Coal washing | W | W | 12.67 | -- | -- | -- | W | W | 11.57 | -- | -- | -- | 18 | 199 | 11.06 |
| Roofing granules and fillers | 36 | 619 | 17.19 | 40 | 444 | 11.10 | 288 | 3,415 | 11.86 | 39 | 577 | 14.79 | 403 | 5,056 | 12.55 |
| Hydraulic fracturing | W | W | 17.47 | 1,396 | 29,853 | 21.38 | W | W | 17.47 | 47 | 1,045 | 22.23 | 2,102 | 42,417 | 20.18 |
| Other uses, specified | 1,200 | 14,059 | 11.72 | 3,706 | 41,794 | 11.28 | 2,540 | 39,609 | 15.59 | 820 | 15,902 | 19.39 | XX | XX | XX |
| Other uses, unspecified[3] | 138 | 1,727 | 12.51 | 158 | 1,451 | 9.18 | 1,968 | 11,817 | 6.00 | 182 | 890 | 4.89 | 2,446 | 15,885 | 6.49 |
| Total[1] or average | 3,701 | 45,179 | 12.21 | 11,609 | 144,935 | 12.48 | 10,489 | 128,564 | 12.26 | 3,270 | 52,048 | 15.92 | 29,070 | 370,730 | 12.75 |
| Gravel: Metallurgical: | | | | | | | | | | | | | | | |
| Silicon, ferrosilicon | -- | -- | -- | W | W | 10.00 | W | W | 6.44 | 51 | 917 | 17.98 | 315 | 2,771 | 8.80 |
| Filtration | W | W | 10.40 | W | W | 18.75 | W | W | 24.00 | W | W | 7 | 23 | 383 | 16.65 |
| Grinding | -- | -- | -- | -- | -- | -- | W | W | 8.60 | W | W | (2) | 5 | 43 | 8.60 |
| Other uses | -- | -- | -- | -- | -- | -- | W | W | 10.21 | W | W | (2) | 15 | 143 | 9.53 |
| Total[1] or average | W | W | 10.40 | 61 | 750 | 12.30 | W | W | 6.75 | 53 | 924 | 17.43 | 357 | 3,340 | 9.36 |
| Grand total[1] or average | W | W | 14.9 | 11,670 | 145,685 | 12.48 | W | W | 12.13 | 3,323 | 52,972 | 15.94 | 29,430 | 374,070 | 12.71 |

W Withheld to avoid disclosing company proprietary data; included with "Other uses, specified." XX Not applicable.

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 1/2 unit.

[3] Mostly estimated total production, plus other uses (small quantities) as reported by the producers.

## Table 11.—Transportation of industrial sand and gravel in the United States in 1985 to site of first sale or use

| Method of shipment | Quantity (thousand short tons) | Percent of total |
|---|---|---|
| Truck | 23,620 | 80 |
| Rail | 5,401 | 18 |
| Waterway | 165 | 1 |
| Not shipped, used at site | 245 | 1 |
| Total | [1]29,430 | 100 |

[1] Data do not add to total shown because of independent rounding.

## Table 12.—U.S. exports of industrial sand, by country

(Thousand short tons and thousand dollars)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | F.a.s. value[1] | Quantity | F.a.s. value[1] |
| North America: | | | | |
| Bahamas | 3 | 115 | 1 | 80 |
| Canada | 1,045 | 13,587 | 739 | 10,926 |
| Costa Rica | 10 | 151 | (2) | 68 |
| Dominican Republic | 3 | 231 | 1 | 64 |
| Mexico | 70 | 2,245 | 50 | 1,516 |
| Panama | 5 | 152 | 9 | 239 |
| Other | 1 | 390 | 4 | 208 |
| Total[3] | 1,138 | 16,871 | 805 | 13,101 |
| South America: | | | | |
| Argentina | 4 | 238 | (2) | 12 |
| Chile | (2) | 73 | (2) | 135 |
| Colombia | (2) | 102 | 1 | 161 |
| Ecuador | (2) | 84 | 6 | 144 |
| Peru | 6 | 693 | 7 | 754 |
| Venezuela | 1 | 171 | (2) | 114 |
| Other | [r](2) | [r]50 | (2) | 34 |
| Total[3] | 11 | 1,410 | 15 | 1,354 |
| Europe: | | | | |
| Belgium | 1 | 312 | 6 | 327 |
| France | (2) | 128 | 1 | 203 |
| Germany, Federal Republic of | 5 | 1,381 | 2 | 444 |
| Netherlands | 3 | 1,573 | 6 | 2,300 |
| Norway | 1 | 86 | 2 | 584 |
| United Kingdom | 6 | 441 | 9 | 484 |
| Other | 4 | [r]453 | 3 | 315 |
| Total[3] | 20 | 4,378 | 28 | 4,656 |
| Asia: | | | | |
| Indonesia | 2 | 253 | 2 | 142 |
| Japan | 4 | 1,149 | 4 | 700 |
| Singapore | 4 | 883 | 4 | 780 |
| Other | 2 | 466 | 2 | 588 |
| Total[3] | 11 | 2,752 | 11 | 2,211 |
| Middle East and Africa: | | | | |
| Turkey | 3 | 565 | -- | -- |
| Saudi Arabia | 1 | 73 | 1 | 156 |
| United Arab Emirates | 2 | 672 | 3 | 585 |
| Other | 3 | 496 | 1 | 202 |
| Total | 9 | 1,806 | 5 | 943 |
| Oceania | 3 | 444 | 2 | 316 |
| Grand total[3] | 1,193 | 27,656 | 866 | 22,580 |

[r] Revised.

[1] Value of material at U.S. port of export; based on transaction price, including all charges incurred in placing material alongside ship.

[2] Less than 1/2 unit.

[3] Data may not add to totals shown because of independent rounding.

## Table 13.—U.S. imports for consumption of industrial sand, by country

(Thousand short tons and thousand dollars)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | C.i.f. value[1] | Quantity | C.i.f. value[1] |
| Antigua | 5 | 83 | 14 | 92 |
| Australia | 6 | 167 | 42 | 737 |
| Bahamas | 8 | 15 | -- | -- |
| British Virgin Islands | 1 | 17 | 5 | 89 |
| Canada | 5 | 155 | 2 | 115 |
| Japan | (2) | 4 | 11 | 16 |
| Spain | -- | -- | 3 | 30 |
| United Kingdom | (2) | 1 | 2 | 53 |
| Other | r1 | r485 | 3 | 382 |
| Total[3] | 26 | 926 | 81 | 1,513 |

rRevised.

[1] Value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.

[2] Less than 1/2 unit.

[3] Data may not add to totals shown because of independent rounding.

# Silicon

## By Gerald F. Murphy[1]

Overall demand for silicon materials in the United States in 1985 was slightly lower than that of 1984, a consequence of a decrease in production by the iron and steel and aluminum industries. Production and shipments of silicon ferroalloys and silicon metal declined by significant amounts. Imports of silicon materials overall increased by a little more than 20% while domestic production declined by about 10%. As a result, domestic producers' market share declined. However, silicon metal imports were a little more than double those of 1984. Exports decreased substantially, by more than one-half, and remained small compared with imports. Owing to competition from low-priced imports and a weakening demand by consuming industries, domestic producers lowered the prices for metallurgical-grade silicon metal at the end of the third quarter and for the 50% and 75% ferrosilicon grades toward yearend. World demand for silicon materials increased slightly compared with that of 1984.

**Domestic Data Coverage.**—Domestic production data for the silicon commodity are developed by the Bureau of Mines by means of monthly and annual voluntary domestic surveys. Typical of these surveys is the monthly "Silicon Alloys" survey. Of the 18 canvassed operations to which a survey collection request was made, all responded, representing 100% of the total production shown in table 1.

**Table 1.—Production, shipments, and stocks of silvery pig iron, ferrosilicon, and silicon metal in the United States in 1985**

(Short tons, gross weight, unless otherwise specified)

| Alloy | Silicon content (percent) | | Producers' stocks as of Dec. 31, 1984 | Gross production | Net shipments | Producers' stocks as of Dec. 31, 1985 |
|---|---|---|---|---|---|---|
| | Range | Typical | | | | |
| Silvery pig iron | 5-24 | 18 | W | W | W | W |
| Ferrosilicon (including briquets) | 25-55 | 48 | 60,579 | 349,491 | 263,152 | 97,738 |
| Do | 56-95 | 76 | 29,157 | 91,045 | 80,058 | 24,858 |
| Silicon metal (excluding semiconductor grades) | 96-99 | 98 | 10,432 | 122,787 | 121,640 | 9,753 |
| Miscellaneous silicon alloys (excluding silicomanganese) | 32-65 | -- | 14,300 | 65,408 | 61,523 | 14,670 |

W Withheld to avoid disclosing company proprietary data.

**Legislation and Government Programs.**—Senate bill 262 and its counterpart, House bill 976 entitled "Fair Trade in Ferroalloys Act," were introduced in the U.S. Senate and the House of Representatives on January 24 and February 6, respectively. The Fair Trade in Ferroalloys Act, aimed at preserving the domestic ferroalloys industry, would establish a "breakpoint" tariff system whereby certain ferroalloys imports entering the United States below an established fair market price would be automatically assessed a tariff. The Senate bill was referred to the Senate Finance Committee and the House bill was referred to the House Ways and Means Committee for consideration. On May 21, the U.S. Senate adopted an amendment (No. 168) to the Department of Defense fiscal year 1986 Authorization Bill (S. 1160), which requires the U.S. Department of Defense to conduct a study to determine what impact the loss of all domestic ferroalloy production capacity would have on the U.S. industrial base and military preparedness.

Senate bill 1533, National Security Trade Act of 1985, was introduced in the U.S. Senate on July 31 to amend section 232 of the 1962 Trade Expansion Act. Final responsibility for decisions on trade relief cases and setting time limits would rest with the U.S. Trade Representative. On October 9, Senate bill 1753 was introduced in the U.S. Senate to amend title II of the Trade Act of 1974, adoption of which would eliminate the discretionary power of the President to grant import relief. The administration outlined a "strike force" consisting of six high-level administration officials that would monitor other countries' export barriers to U.S. goods and unfair subsidies of foreign goods that compete in the U.S. market. The administration also announced an agreement by France, the Federal Republic of Germany, Japan, the United Kingdom, and the United States on a joint action to weaken the U.S. dollar in an attempt to slow the protectionist pressures on Congress to curb imports and to promote U.S. exports.

A report entitled "Can the U.S. Ferroalloy Industry Survive?," released by the Congressional Research Service of the Library of Congress, examined key changes in the structure of the U.S. ferroalloys industry since the early 1970's. The report focused on the changing competitive posture of domestic producers of ferrosilicon, among others.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. The status of silicon carbide was deferred until further detailed studies could be made. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

## DOMESTIC PRODUCTION

Production and shipments of silicon ferroalloys and silicon metal overall showed significant decreases in 1985, compared with those of 1984, following comparable declines in the iron and steel and aluminum industries. The 56% to 95% ferrosilicon range declined the most. Both production and shipments declined by about 30%. Magnesium ferrosilicon accounts for the major portion of the miscellaneous silicon alloys category, the remainder in this class being calcium-silicon, silicon-manganese-zirconium, and rare-earth silicides. Data for silvery pig iron are withheld because there was only one producer.

Producer stocks of 25% to 55% ferrosilicon increased by about two-thirds, while those of 56% to 95% ferrosilicon showed a decrease of about 15%. Stocks of miscellaneous silicon alloys were relatively unchanged.

Foote Mineral Co., Exton, PA, announced in September plans to sell its specialty products lines including proprietary technology, trade names, and patents to SKW Alloys Inc., Niagara Falls, NY, effective January 3, 1986. As compensation, Foote will participate in the profits generated by SKW Alloys in the manufacture and sales of the product lines over the next 6 years. As a result of this transaction, Foote closed its Graham, WV, ferroalloys plant on December 31, 1985. In February 1985, Ohio Ferro-Alloys Corp. (OFA), Dayton, OH, closed its Powhatan Point silicon metal plant for the balance of the year. The company subsequently concentrated all of its silicon metal production in its Montgomery, AL, facility. OFA's third plant in Philo, OH, which produced ferrosilicon, had been shut down in September 1984. The company also secured a 5-year agreement to sell silicon metal to General Electric Co.'s (GE) Silicones Product Div. and concluded a $3 million loan agreement with GE's Credit Corp. The Bonneville Power Administration approved M. A. Hanna Co.'s request for a 5-year extension of its current offpeak power rate for Hanna's smelter at Riddle, OR. Additionally, a new 5-year labor contract was finalized between Hanna and unionized workers at Riddle.

International Minerals & Chemical Corp. (IMC), Northbrook, IL, completed an expansion that tripled production of high-purity quartz at its feldspar beneficiation complex in Spruce Pine, NC. Markets for IMC quartz include fused quartz producers, semiconductor manufacturers, and the refractory and fiber-optic components industries.

Estimated ferrous scrap consumption by the domestic silicon ferroalloys industry to produce silicon ferroalloys was 280,000 tons in 1985, compared with 310,000 tons in 1984.

**Table 2.—Producers of silicon alloys and/or silicon metal in the United States in 1985**

| Producer | Plant location | Product |
|---|---|---|
| Aluminum Co. of America, Northwest Alloys Inc | Addy, WA | FeSi and Si. |
| Dow Corning Corp | Springfield, OR | Si. |
| Elkem Metals Co | Alloy, WV | FeSi and Si. |
| Do | Ashtabula, OH | FeSi. |
| Foote Mineral Co., Ferroalloys Div | Graham, WV | Do. |
| Do | Keokuk, IA | Silvery pig iron. |
| M. A. Hanna Co.: | | |
| Hanna Nickel Smelting Co | Riddle, OR | FeSi. |
| Silicon Div | Wenatchee, WA | FeSi and Si. |
| International Minerals & Chemical Corp., Industry Group, TAC Alloys Div | Bridgeport, AL | FeSi. |
| Do | Kimball, TN | Do. |
| Moore McCormack Resources Inc., Globe Metallurgical Inc | Beverly, OH | FeSi and Si. |
| Do | Selma, AL | Si. |
| Ohio Ferro-Alloys Corp | Montgomery, AL | FeSi and Si. |
| Do | Powhatan Point, OH | Si. |
| Reactive Metals & Alloys Corp | West Pittsburgh, PA | FeSi. |
| Reynolds Metals Co | Sheffield, AL | Si. |
| SKW Alloys Inc | Calvert City, KY | FeSi. |
| Do | Niagara Falls, NY | Do. |

## CONSUMPTION AND USES

Overall reported consumption of silicon materials in 1985 decreased by about 5%, based on silicon content, compared with that of 1984. The more pronounced decreases occurred for the 56% to 70% and 81% to 95% ferrosilicon ranges, but these grades remained a small part of the total ferrosilicon used. Moderate declines were observed for the 50% and 75% ferrosilicon grades and silicon carbide. The largest demand was for silicon metal and the 50% ferrosilicon grade, followed, on the basis of silicon content, by 75% ferrosilicon, miscellaneous silicon alloys, silicon carbide, and silvery pig iron. The decreasing order of end uses for silicon materials was steel, cast iron, silicones and silanes, and nonferrous alloys, with about 60% of consumption being accounted for by ferrous applications. Cast-iron production consumed the greatest amounts of silicon carbide, miscellaneous silicon alloys, and silvery pig iron, while steelmaking was the biggest user of 75% and 85% ferrosilicon. Iron foundries and steel plants together accounted for 95% of 50% ferrosilicon usage; 90% of silicon metal went into nonferrous alloys and silicones and silanes.

Decreases in consumption paralleled declines in major markets for silicon alloys. Iron foundries and the steel industry each experienced production losses of a little more than 5%. The aluminum industry, which uses silicon metal to make wrought and cast products, suffered from an excess of supply over demand and reduced production by about 15%. The decrease was attributed to overproduction in 1984. Consumption of silicon metal for silicones and silanes increased slightly in 1985, compared with that of 1984.

Silicon metal produced by tonnage methods is used as raw material for the manufacture of the relatively small quantity of ultrahigh-purity polycrystalline silicon for semiconductors, solar cells (photovoltaic cells), and other highly specialized applications. The Bureau of Mines does not collect data on these specialty grades of silicon, which have a high unit value. In 1985, domestic production of polycrystalline silicon was estimated at 1,800 tons.

Overall, consumer stocks of silicon material declined 15%. The largest decreases occurred for the 56% to 70% and 81% to 95% ferrosilicon ranges and for silicon carbide.

Union Carbide Corp. began a project to

double its production capacity to 2,400 tons per year at its new Moses Lake, WA, polycrystalline silicon plant. The additional capacity was expected to meet anticipated demand from the semiconductor industry for polycrystalline silicon. Some of the additional capacity was expected to become available in late 1986.

Monsanto Electronic Materials Co. (MEMC), St. Louis, MO, formed a 50-50 partnership with Dongbu Industrial Inc. to produce silicon wafers for the semiconductor industry. The new facility, Korsil Inc., will be in Gumi Industrial Park, Republic of Korea. The plant was expected to be completed in 1986. MEMC also began construction of a silicon wafer manufacturing and research plant in Utsunomiya, Tochigi, Japan. The project's first phase was expected to be completed by mid-1986. Nippon Kokan K.K. purchased GE's Great Western Silicon polycrystalline silicon plant in Arizona. The plant has the capacity to produce about 200 tons per year of high-purity silicon. Polycrystalline Silicon Technology Inc., Arizona, developed a laboratory version of polycrystalline silicon plants. The self-contained units can be used to investigate the Siemens process for production of high-purity silicon.

Dynamit Nobel A.G., through its subsidiary Kay-Fries Inc., purchased Petrarch Systems Inc., Bristol, PA. Petrarch specializes in high-technology silicon. Markets for its products include optical fiber cable jacketing, medical implants, electronics, and catalysts. The company began an expansion program to increase its capacity for silanes and silicone compounds by doubling the size of its facilities in Bristol.

### Table 3.—Consumption, by major end use, and stocks of silicon alloys and metal in the United States in 1985

(Short tons, gross weight, unless otherwise specified)

| End use | Silicon content (percent) | Silvery pig iron | Ferrosilicon[1] | | | | Silicon metal | Miscellaneous silicon alloys[2] | Silicon carbide[3] |
|---|---|---|---|---|---|---|---|---|---|
| | Range | 5-24 | 25-55 | 56-70 | 71-80 | 81-95 | 96-99 | -- | 63-70 |
| | Typical | 18 | 48 | 65 | 76 | 85 | 98 | 48 | 64 |
| Steel: | | | | | | | | | |
| Carbon | | (4) | 48,864 | -- | 19,402 | (4) | (4) | 1,969 | (4) |
| Stainless and heat-resisting | | -- | 33,848 | -- | 27,315 | (4) | 123 | (4) | -- |
| Full alloy | | (4) | 15,417 | -- | 6,543 | (4) | (4) | 562 | -- |
| High-strength, low-alloy | | -- | 6,526 | -- | 573 | (4) | 35 | 125 | (4) |
| Electric | | -- | (4) | (5) | (4) | -- | -- | (4) | -- |
| Tool | | -- | (4) | -- | 1,683 | -- | (4) | (4) | -- |
| Unspecified | | 44 | 6,466 | -- | 18,742 | 800 | 1,903 | 172 | 223 |
| Total | | 44 | 111,121 | (5) | 74,258 | 800 | 2,061 | 2,828 | 223 |
| Cast irons | | 11,288 | 110,741 | (5) | 19,043 | 314 | 51 | 37,995 | 28,309 |
| Superalloys | | 7 | 367 | -- | 74 | 59 | 60 | 3 | -- |
| Aluminum alloys | | -- | (5) | -- | -- | (5) | 48,479 | (5) | -- |
| Other alloys | | 11 | 2,897 | -- | 107 | 4 | 7,376 | 11 | -- |
| Silicones and silanes | | -- | -- | -- | -- | -- | 63,235 | -- | -- |
| Miscellaneous and unspecified | | -- | 7,653 | 2,750 | 30 | 228 | [6]11,167 | 54 | -- |
| Total | | 11,350 | 232,779 | 2,750 | 93,512 | 1,405 | 132,429 | 40,891 | 28,532 |
| Percent of 1984 | | 119 | 88 | 66 | 91 | 59 | 116 | 133 | 88 |
| Total silicon content[7] | | 2,043 | 111,734 | 1,788 | 71,069 | 1,194 | 129,780 | 19,628 | 18,260 |
| Consumers' stocks, Dec. 31 | | 881 | 10,013 | 116 | 6,559 | 118 | 5,029 | 1,743 | 940 |

[1] Includes briquets.

[2] Primarily magnesium-ferrosilicon but also includes other silicon alloys. Average silicon content estimated as 48%, based on 1985 production survey.

[3] Does not include silicon carbide for abrasive or refractory uses.

[4] Included with "Steel: Unspecified."

[5] Included with "Miscellaneous and unspecified."

[6] Includes an estimated 11,000 tons consumed for unspecified chemicals.

[7] Estimated based on typical percent content.

## PRICES

Published prices for domestic silicon materials remained unchanged for much of 1985. However, domestic producers lowered their prices for metallurgical-grade silicon metal at the end of the third quarter and for the 50% and 75% ferrosilicon grades toward yearend. The price reductions were attributed to competition from low-priced imports, a falloff in demand for silicon metal by the aluminum industry in the second half of the year, and weaker demand by the steel and ferrous foundry industries. Despite these decreases, the average price per year for major silicon materials increased in 1985 compared with that of 1984. For example, on a contained-silicon basis, ferrosilicon increased from 42.9 cents per pound in 1984 to 44.6 in 1985, 75% ferrosilicon increased from 44.3 to 46.1, and silicon metal containing 1% maximum iron increased from 62.9 to 63.3.

Published prices of imported silicon ferroalloys showed a downward trend throughout the year, while the price of imported silicon metal showed an upward trend for the first half of 1985, followed by a steady decline for the remainder of the year. Most imported silicon materials were priced significantly lower than comparable domestically produced materials. For example, the average price per year for imported 50% ferrosilicon, 75% ferrosilicon, and silicon metal containing 1% iron was lower than domestically produced material by 18%, 24%, and 9%, respectively.

Although posted prices for domestically produced silicon materials were, in general, much higher than those of imports, discounting by domestic producers was reported throughout the industry.

## FOREIGN TRADE

Exports of ferrosilicon declined by more than one-half in quantity and by 40% in value, compared with that of 1984. The largest quantity went to Canada, 9,425 tons, which accounted for about 70% and 60% of total quantity and value, respectively. Exports went to 27 countries. Silicon metal exports also showed a comparable decline, about one-half in quantity and 30% in value. Most of the metal was exported to Mexico (625 tons), Japan (583 tons), and Canada (413 tons), making up about 75% in terms of total quantity and about 50% of total value. A relatively small quantity, 118 tons, was shipped to Malaysia. Combined exports to Japan and Malaysia accounted for about one-third of total quantity but about 85% of total value. Exports went to 31 countries.

Compared with those of 1984, imports of ferrosilicon increased about 8% in volume but were little changed in value. Silicon metal imports increased a little more than 100% in quantity and about 50% in value. Imports of 75% ferrosilicon were the most significant on a volume basis. Overall total imports of ferrosilicon and silicon metal increased a little more than 20%.

The 75% grade (60% and 80% silicon) accounted for a little more than 60% of ferrosilicon imports. Norway shipped one-fourth of the total in this range, while Brazil and Venezuela, each with a little more than one-fifth of the total, were the next largest sources. Imports in this range from Canada increased notably compared with those of 1984. The next largest import class was regular-grade 50% ferrosilicon (30% to 60% silicon), which amounted to about one-fourth of all ferrosilicon imports. The main sources of this material were, in decreasing order, the U.S.S.R., Canada, and Venezuela, which accounted for about 80% of the total in this class. Average silicon content of all imported ferrosilicon in 1985 decreased to 66% from 67% in 1984.

Imports of silicon metal in the 96% to 99% range showed an increase of 40%, compared with those of 1984. The main sources of this material were Canada and Yugoslavia, which accounted for about 75% of the total. However, imports of silicon metal in the 99% to 99.7% range increased about 140%, compared with those of 1984. Total imports of silicon metal increased by a little more than 100% in terms of gross weight, compared with those of 1984. Brazil, Canada, and Portugal were the dominant sources of commercial-purity silicon metal. The Federal Republic of Germany, Italy, and Japan supplied over 90% of the imported high-purity semiconductor-grade silicon, which is included in the over 99.7% silicon import class.

Imports of silicon materials, on a gross-weight basis, represented a larger share of the domestic market, increasing from about one-fifth in 1984 to a little more than one-quarter in 1985.

The very large increase in silicon metal imports and a small increase in ferrosilicon imports combined with a marked decline in ferrosilicon and silicon metal exports left the United States a net importer of silicon materials. Net imports of silicon materials amounted to about 189,000 tons and a trade deficit of about $83 million. The administration also announced an agreement by the United States with four other leading industrial nations on a joint action to weaken the U.S. dollar in an attempt to slow the protectionist pressures on Congress to curb imports and to promote U.S. exports.

**Table 4.—U.S. exports of ferrosilicon and silicon metal**

| Year | Quantity (short tons) | Value (thousands) |
|---|---|---|
| FERROSILICON | | |
| 1981 | 15,768 | $12,136 |
| 1982 | 14,932 | 11,996 |
| 1983 | 13,338 | 10,712 |
| 1984 | 29,364 | 21,135 |
| 1985 | 12,969 | 12,671 |
| SILICON METAL | | |
| 1981 | 8,673 | 57,001 |
| 1982 | 2,411 | 34,335 |
| 1983 | 2,767 | 47,826 |
| 1984 | 4,420 | 88,543 |
| 1985 | 2,120 | 61,647 |

Source: Bureau of the Census

**Table 5.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country**

| Grade and country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | | Value (thousands) | Quantity (short tons) | | Value (thousands) |
| | Gross weight | Silicon content | | Gross weight | Silicon content | |
| Ferrosilicon: | | | | | | |
| Over 8% but not over 30% silicon: | | | | | | |
| Canada | 42 | 6 | $3 | 152 | 23 | $9 |
| Germany, Federal Republic of | -- | -- | -- | 171 | 17 | 5 |
| United Kingdom | 5 | 1 | 10 | 23 | 4 | 27 |
| Total[1] | 46 | 7 | 13 | 345 | 43 | 41 |
| Over 30% but not over 60% silicon, with over 2% magnesium: | | | | | | |
| Brazil | 5,564 | 2,530 | 2,845 | 3,973 | 1,822 | 2,462 |
| Canada | 351 | 178 | 151 | 774 | 365 | 223 |
| France | 964 | 446 | 662 | 727 | 340 | 519 |
| Germany, Federal Republic of | 256 | 143 | 321 | 212 | 106 | 289 |
| Italy | 273 | 122 | 201 | 99 | 45 | 71 |
| Japan | 182 | 82 | 311 | 127 | 57 | 215 |
| Norway | 3,244 | 1,488 | 2,688 | 1,662 | 743 | 1,186 |
| Spain | 78 | 41 | 73 | 12 | 5 | 17 |
| Total[1] | 10,912 | 5,030 | 7,252 | 7,586 | 3,484 | 4,981 |
| Over 30% but not over 60% silicon, not elsewhere classified: | | | | | | |
| Argentina | -- | -- | -- | 66 | 40 | 60 |
| Brazil | 7,160 | 3,473 | 2,428 | 3,135 | 1,532 | 977 |
| Canada | 7,221 | 3,627 | 2,113 | 11,547 | 5,568 | 3,697 |
| France | 2,703 | 1,578 | 2,694 | 2,628 | 1,497 | 2,209 |
| Germany, Federal Republic of | 868 | 480 | 948 | 261 | 145 | 270 |
| Italy | 76 | 41 | 72 | -- | -- | -- |
| Japan | 18 | 8 | 31 | 36 | 16 | 60 |
| Netherlands | 18 | 11 | 16 | -- | -- | -- |
| Norway | 1,090 | 437 | 408 | -- | -- | -- |
| Spain | 939 | 589 | 1,019 | 1,111 | 644 | 1,103 |
| U.S.S.R | 11,514 | 5,424 | 3,151 | 16,132 | 7,518 | 4,542 |
| Venezuela | -- | -- | -- | 6,969 | 3,828 | 1,672 |
| Total[1] | 31,607 | 15,668 | 12,880 | 41,887 | 20,788 | 14,590 |
| Over 60% but not over 80% silicon, with over 3% calcium: | | | | | | |
| Argentina | -- | -- | -- | 357 | 222 | 368 |
| Brazil | 4,436 | 2,802 | 3,841 | 6,134 | 3,860 | 5,377 |
| Canada | -- | -- | -- | 31 | 24 | 15 |
| France | 1,118 | 691 | 1,209 | 1,080 | 653 | 1,052 |
| Germany, Federal Republic of | 1,054 | 678 | 999 | 602 | 367 | 576 |

See footnotes at end of table.

## Table 5.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country —Continued

| Grade and country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | | Value (thousands) | Quantity (short tons) | | Value (thousands) |
| | Gross weight | Silicon content | | Gross weight | Silicon content | |
| Ferrosilicon —Continued | | | | | | |
| Over 60% but not over 80% silicon, with over 3% calcium —Continued | | | | | | |
| Italy | 146 | 104 | $148 | 37 | 24 | $35 |
| Mexico | 44 | 26 | 10 | -- | -- | -- |
| Spain | -- | -- | -- | 312 | 191 | 291 |
| Total[1] | 6,798 | 4,301 | 6,207 | 8,554 | 5,340 | 7,714 |
| Over 60% but not over 80% silicon, not elsewhere classified: | | | | | | |
| Argentina | 1,743 | 1,319 | 759 | 5,741 | 4,416 | 2,817 |
| Belgium-Luxembourg | 17 | 13 | 53 | -- | -- | -- |
| Brazil | 17,793 | 13,311 | 9,209 | 21,120 | 15,918 | 10,411 |
| Canada | 8,652 | 6,564 | 5,096 | 12,877 | 9,812 | 6,590 |
| Chile | 1,068 | 822 | 598 | -- | -- | -- |
| France | 575 | 440 | 492 | 413 | 317 | 393 |
| Germany, Federal Republic of | 968 | 727 | 1,401 | 1,079 | 802 | 1,575 |
| Iceland | 2,582 | 1,937 | 1,259 | 5,295 | 4,011 | 2,229 |
| Israel | 4,327 | 3,245 | 1,919 | -- | -- | -- |
| Norway | 23,710 | 17,746 | 11,619 | 23,598 | 17,632 | 10,293 |
| Poland | 799 | 589 | 372 | -- | -- | -- |
| Portugal | 4,021 | 3,056 | 2,099 | -- | -- | -- |
| South Africa, Republic of | 1,382 | 1,079 | 796 | 4,144 | 3,168 | 2,076 |
| Sweden | 111 | 83 | 111 | -- | -- | -- |
| United Kingdom | -- | -- | -- | 19 | 14 | 11 |
| Venezuela | 25,377 | 19,074 | 10,046 | 20,768 | 15,302 | 9,297 |
| Yugoslavia | -- | -- | -- | 1,101 | 835 | 529 |
| Total[1] | 93,125 | 70,005 | 45,829 | 96,154 | 72,228 | 46,222 |
| Over 80% but not over 90% silicon: | | | | | | |
| Belgium-Luxembourg | 76 | 69 | 59 | 19 | 17 | 16 |
| Brazil | 220 | 187 | 158 | 498 | 422 | 312 |
| Canada | 55 | 45 | 19 | -- | -- | -- |
| France | 38 | 32 | 23 | -- | -- | -- |
| Norway | 441 | 383 | 203 | 358 | 315 | 132 |
| Spain | 231 | 206 | 156 | -- | -- | -- |
| Total[1] | 1,063 | 923 | 619 | 875 | 754 | 460 |
| Over 90% but not over 96% silicon: | | | | | | |
| Belgium-Luxembourg | 38 | 36 | 33 | -- | -- | -- |
| Canada | 20 | 20 | 11 | -- | -- | -- |
| Germany, Federal Republic of | -- | -- | -- | 20 | 19 | 11 |
| Italy | 41 | 38 | 32 | -- | -- | -- |
| South Africa, Republic of | ([2]) | ([2]) | ([2]) | -- | -- | -- |
| Total[1] | 100 | 94 | 76 | 20 | 19 | 11 |
| Total ferrosilicon[1] | 143,651 | 96,027 | 72,874 | 155,421 | 102,656 | 74,019 |
| Silicon metal: | | | | | | |
| Over 96% but not over 99% silicon: | | | | | | |
| Argentina | -- | NA | -- | 440 | NA | 475 |
| Brazil | -- | | -- | 55 | | 48 |
| Canada | 3,101 | | 3,425 | 4,257 | | 4,898 |
| France | 114 | | 106 | 65 | | 79 |
| Italy | -- | | -- | 1,134 | | 1,020 |
| Portugal | 22 | | 15 | -- | | -- |
| South Africa, Republic of | 244 | | 247 | -- | | -- |
| Spain | 105 | | 71 | 116 | | 115 |
| Sweden | -- | | -- | 551 | | 585 |
| Switzerland | 37 | | 29 | 19 | | 15 |
| United Kingdom | -- | | -- | 36 | | 37 |
| Yugoslavia | 3,130 | | 3,219 | 2,680 | | 2,412 |
| Total[1] | 6,753 | NA | 7,113 | 9,353 | NA | 9,684 |
| Over 99% but not over 99.7% silicon: | | | | | | |
| Argentina | 1,203 | 1,181 | 1,322 | 1,520 | 1,508 | 1,482 |
| Belgium-Luxembourg | 115 | 107 | 103 | 18 | 18 | 18 |
| Brazil | 2,665 | 2,640 | 2,792 | 13,283 | 13,122 | 13,071 |
| Canada | 5,123 | 5,076 | 6,196 | 6,027 | 5,959 | 7,231 |
| China | 441 | 434 | 411 | 165 | 162 | 157 |
| Denmark | ([2]) | ([2]) | 1 | -- | -- | -- |
| France | 3,988 | 3,956 | 4,354 | 3,869 | 3,837 | 4,012 |

See footnotes at end of table.

### Table 5.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country —Continued

| Grade and country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | | Value (thousands) | Quantity (short tons) | | Value (thousands) |
| | Gross weight | Silicon content | | Gross weight | Silicon content | |
| Silicon metal —Continued | | | | | | |
| Over 99% but not over 99.7% silicon —Continued | | | | | | |
| Germany, Federal Republic of | (2) | (2) | $1 | -- | -- | -- |
| Italy | 337 | 335 | 347 | 1,093 | 1,087 | $1,165 |
| Netherlands | -- | -- | -- | 136 | 134 | 127 |
| Norway | 660 | 655 | 693 | 1,081 | 1,072 | 1,100 |
| Portugal | 887 | 880 | 930 | 6,386 | 6,322 | 6,737 |
| South Africa, Republic of | 1,745 | 1,729 | 1,840 | 3,932 | 3,900 | 4,128 |
| Spain | 252 | 250 | 259 | 1,280 | 1,267 | 1,111 |
| Sweden | -- | -- | -- | 1,111 | 1,101 | 1,088 |
| Switzerland | -- | -- | -- | 757 | 749 | 785 |
| Venezuela | -- | -- | -- | 20 | 20 | 21 |
| Yugoslavia | 172 | 166 | 113 | 884 | 869 | 780 |
| Total[1] | 17,588 | 17,408 | 19,361 | 41,563 | 41,128 | 42,954 |
| Over 99.7% silicon: | | | | | | |
| Belgium-Luxembourg | -- | | -- | 19 | | 16 |
| Canada | 49 | | 121 | -- | | -- |
| China | 35 | | 398 | 1 | | 50 |
| Denmark | 21 | | 502 | 21 | | 639 |
| Dominican Republic | -- | | -- | 4 | | 172 |
| Finland | (2) | | 6 | -- | | -- |
| France | 22 | | 370 | 5 | | 591 |
| German Democratic Republic | (2) | | 2 | 1 | | 52 |
| Germany, Federal Republic of | 618 | | 21,608 | 598 | | 21,565 |
| Hong Kong | 5 | NA | 289 | -- | NA | -- |
| Israel | (2) | | 3 | -- | | -- |
| Italy | 93 | | 3,547 | 80 | | 3,353 |
| Japan | 84 | | 1,952 | 144 | | 3,623 |
| Korea, Republic of | (2) | | 6 | -- | | -- |
| Malaysia | (2) | | 9 | (2) | | 1 |
| Netherlands | -- | | -- | (2) | | 22 |
| Sweden | 4 | | 37 | -- | | -- |
| Switzerland | (2) | | 57 | 13 | | 640 |
| United Kingdom | -- | | -- | (2) | | 5 |
| Total[1] | 880 | NA | 28,907 | 885 | NA | 30,729 |
| Total silicon metal | 25,221 | XX | 55,381 | 51,801 | XX | 83,367 |

NA Not available. XX Not applicable.

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 1/2 unit.

Source: Bureau of the Census.

## WORLD REVIEW

World demand for silicon materials increased slightly compared with that of 1984, owing to only a small increase in production by the world iron and steel industry, the major consumer of ferrosilicon. Worldwide overcapacity made it difficult for producers to maintain profitability. European Economic Community (EEC) ferrosilicon producers met with EEC commission officials to discuss an increase in the low level of prices, set in 1983, of ferrosilicon delivered to the EEC border. Subsequently, the Commission began to monitor the ferrosilicon market and asked producers from countries accused of dumping in 1983 to provide details of all transactions in the EEC market since April 1985. If the non-EEC producers do not agree to an increase of the minimum price set in 1983, the EEC would be expected to use other ways to seek a firming in prices, such as the EEC antidumping legislation. The EEC Council of Ministers also agreed to maintain the duty-free quota for imports of ferrosilicon for 1986 at about 14,000 tons, of which the Federal Republic of Germany will be the main beneficiary.

**Argentina.**—A shipment amounting to about 4,400 tons of ferrosilicon produced by Industrias Siderurgicas Grassi S.A. was delivered to Japan in 1985, the largest shipment ever of Argentine ferrosilicon to that country. The company owns a ferroalloy plant with an annual capacity of 11,000 tons.[2]

**Australia.**—Pioneer Concrete Ltd. and French metals producer Pechiney agreed to set up a joint venture to build a silicon plant near Hobart, Tasmania. The new plant, estimated to cost $34 million, would be 60% owned by Pioneer with Pechiney holding the remainder and was expected to be completed by June 1987. The joint venture intends initially to build a single 18.5-megawatt submerged arc furnace, which will produce about 13,000 tons per year of salable alloy or chemical-grade silicon metal, based on technology of Pechiney's subsidiary Pechiney Electrometallurgie.[3]

**Brazil.**—Brazil announced that it planned to triple its output of silicon ferroalloys by 1990 including ferrosilicon and silicon metal. Brazil's aggressive expansion program coincides with diminishing capacity in the United States and Japan. However, worldwide overcapacity is still the main problem facing the world ferroalloy industry.[4]

Italmagnesio S.A. Indústria e Comércio planned to start silicon metal production by March 1986 by converting its 24-megavolt-ampere (MV•A) submerged arc furnace from ferrosilicon production. The furnace was scheduled for operation in January 1986. Its monthly capacity for silicon metal production is rated at about 1,100 tons. Italmagnesio also planned to build a new 13-MV•A furnace for silicon metal production. The unit was expected to be completed by June 1986. Ferro-Ligas Assofun S.A. began installation of an electric furnace for ferrosilicon production at its ferroalloy plant in São Joas da Boa Vista, doubling capacity to about 15,000 tons per year. The company negotiated with Nippon Kokan and Mitsui Co. Ltd., with the aim of establishing a joint venture to raise a part of the financing required for the construction. Cia. Brasileria Carbureto de Calcio (CBCC) converted one of its old 30-MV•A ferrosilicon furnaces to silicon metal production. CBCC brought a new 30-MV•A furnace on-stream about midyear for ferrosilicon production. Production for the new unit was expected to be about 20,000 tons per year. CBCC also signed a contract to supply Toyo Denka Kogyo Co. Ltd. with 5,000 tons per year of ferrosilicon. Eletrovale, a joint venture 60% owned by Cia. Vale do Rio Doce and Eletrometalur S.A. Indústria e Comérico and 20% each by Kawasaki Steel Corp. and Mitsubishi Corp., began construction of its 27,000-ton-per-year ferrosilicon plant. The facility was scheduled to come on-stream toward the end of 1986. Kawasaki Steel will take one-third of the plant's output.

Eletrometalur and Ila og Lilleby Smelteverker A/S of Norway formed a joint venture to produce silicon metal in Brazil. Two 14,000-kilowatt furnaces will be erected at Captain Eneas, Minas Gerais. The 20,000-ton-per-year operation was expected to come on-stream in mid-1987. Plant output will be for export. Alcan Alumínio do Brasil S.A. agreed to sell its ferroalloys division to Cia. Paulista de Ferro-Ligas. Alcan's properties included two single-furnace operations with a total capacity of about 19,000 tons per year of 75% ferrosilicon. A third facility produces silicomanganese. All plants are in Minas Gerais. Cia. de Ferro-Ligas Minas Gerais brought on-stream a 15-M•VA furnace in August, increasing its ferrosilicon capacity from 26,000 tons per year to 40,000 tons of 75% material. Cia. de Ferro-Ligas da Bahia S.A. planned to resume ferrosilicon production by building three 13,000-ton-per-year furnaces in Salvador, Brazil. The first furnace was scheduled for completion in December.

Minerações Brasileiras Reunidas S.A.'s (a Brazilian iron ore producer) plans to build two 15,000-kilovolt-ampere (kV•A) electric furnaces in Pirapora were approved by Conselho de Nao-Ferrosos e de Siderurgia (CONSIDER). The $23 million ferrosilicon plant was to have a capacity to produce about 26,000 tons of ferrosilicon per year. Brazil's Interior Minister approved new investment in the Inoculantes e Ferro-Ligas Nipo Brasileiros S.A. (INONIBRAS) ferrosilicon project. INONIBRAS planned to increase capacity from 7,000 tons per year to 29,000 tons. Osaka Special Alloy Ltd. holds a 30% share in the company, whose smelter is in Mato Grosso State.

**France.**—Pechiney Electrometallurgie, a subsidiary of Pechiney, planned to increase silicon metal capacity by about 14,000 tons per year by switching a ferrosilicon alloy unit to silicon metal production at its Anglefort plant. The new capacity was expected to come on-line in early 1986. Pechiney, the parent company, already has about 83,000 tons of silicon metal capacity. The conversion was made because the market outlook was more promising for silicon metal than for ferrosilicon. In the fourth quarter, Pechiney announced cutbacks in ferrosilicon production, owing to world overcapacity and low prices, and in silicon metal production, owing to some weakening in demand.[5]

**Iceland.**—Icelandic Alloys Ltd.'s production of ferrosilicon dropped below 1984 levels owing to a 7-week shutdown of one of its 35,000-kV•A electric furnaces. The plant operated at full capacity in 1984. Financial restructuring of the company to reduce long-term debt was also completed in 1984. Icelandic Alloys also obtained long-term sales guarantees from Elkem A/S, Norway, and Sumitomo Corp., Japan, which will provide good plant utilization in years of poor demand for ferrosilicon. Construction of the 25,000-ton-per-year silicon metal plant at Reydarsjordur has been delayed until 1986.[6]

**India.**—A letter of intent to produce 2,700 tons per year of silicon metal was issued by the Indian Government to Ispat Alloys Ltd., Balasore, Orissa State. Indian Metals and Ferro Alloys Ltd., Rupali, Orissa, is the only other current producer of silicon metal, with a capacity of 5,500 tons per year. The plant output will go to the semiconductor industry and to the aluminum industry as an additive in aluminum alloys.[7]

**Italy.**—Industria Elettrica (INDEL) planned to install a new 24-MV•A electric furnace for silicon metal production at its Ospitale di Cadore facility by yearend. The expansion will raise INDEL'S capacity to about 31,000 tons per year from a current level of about 19,000 tons. All of the new output was destined for export. INDEL was also producing 22,000 tons per year of 75% ferrosilicon at its Domodossala plant.[8]

**Japan.**—Japan's cabinet approved a plan drafted by its Ministry of International Trade and Industry (MITI) to offer domestic ferrosilicon, ferrochromium, and ferronickel producers financial support in exchange for scrapping or mothballing plant capacity by March 31, 1987. MITI expected most ferrosilicon producers to accept this offer. MITI promised producers who comply with the law on "Extraordinary Measures for Depressed Industries" that they will be exempted from having to pay any or most of their fixed property taxes. MITI said these measures were necessary to offset major inroads by foreign ferroalloys producers whose power costs are much below that of Japanese producers. Japan's ferrosilicon industry has operated at below 50% of its rated capacity owing to the effect of foreign imports. The ferrosilicon companies participating in the plan include Denki Kagaku Kogyo Kabushiki Co. Ltd., Ibiden Co. Ltd., Japan Metals and Chemical Co. Ltd., Toyo Denka, and Ube Denki Kagaku Co. Ltd. Some plants are expected to be mothballed totally, while others would eliminate one or more furnaces.[9]

Japan imported about 113,000 tons of metallurgical-grade silicon metal in 1985, an increase of about 20%, compared with that of 1984. Ferrosilicon imports amounted to approximately 338,000 tons, about a 10% decrease, compared with those of 1984. Production of polycrystalline silicon for the Japanese semiconductor industry was about 1,600 tons, an increase of slightly over 60%, compared with that of 1984.[10]

Showa Denko K.K. planned to begin production of silicon wafers in 1986. A new $91 million facility was to be built in Chichibu City, Saitama Prefecture, north of Tokyo. The company will use a new magnetic crystallization process developed by Sony Corp. to produce 6-inch wafers. Nippon Kokan, Japan's second largest steelmaker, planned to go into the manufacture of silicon wafers in Japan. The company purchased technology for production of polycrystalline silicon from GE. Toyo Soda Manufacturing Co. signed an agreement with Siltec Corp., United States, for a joint venture to produce silicon wafers for the Japanese semiconductor market. Wacker-Chemie GmbH planned to build a silicon rubber compound resin plant at the site of its technical laboratories in Daito Town, Shizuoka.

**Norway.**—Loss of ferrosilicon production owing to furnace breakdowns was experienced by Finnfjord Smelteverk A/S, Orkla Metal A/S, and Hafslund A/S early in 1985. Loss of silicon metal production was reported by Elkem A/S, owing to a furnace breakdown in October at its Fiskaa works.

Hafslund began construction of an 11,000-ton-per-year metal powder plant at its Sarpsborg ferrosilicon facility. The plant, scheduled to come on-line early in 1986, would produce high-quality metal powders by water atomization. Products would include fine-grained 15% ferrosilicon for heavy-medium separation of ores and scrap.

Elkem became sole owner of Elkem Metals Co., United States, and Elkem Metals Canada Inc. Elkem also acquired a 20% share in Officine Elettrochimiche Trentine S.p.A. (OET), Italy, a ferroalloys producer. Additionally, Elkem undertook to market all of OET's products outside Italy. OET makes various specialized, highly refined alloys such as magnesium ferrosilicon, high-purity ferrosilicon, and calcium silicon, among others. Orkla Industrier A/S acquired a 51% interest in Bjoelvefossen A/S, a ferrosilicon producer. Tinfoss Jernverk A/S planned to convert its two 12,000-kV•A ferrosilicon furnaces to silicon metal production, one by July and the other by February 1986.

In December, Elkem announced plans to buy Orkla Industrier's 50% share of Orkla Metal's ferrosilicon plant in Thamshavn and its 51% share in Bjoelvefossen. Elkem also began negotiating with a third Norwegian ferroalloy producer, Tinfoss Jernverk, with the aim to establish a close working agreement in the areas of technology and marketing. With this consolidation of the Norwegian ferrosilicon industry, Elkem would effectively control about 386,000 tons per year of Norwegian ferroalloy capacity and about 110,000 tons per year of U.S. production through its U.S. subsidiary Elkem Metals. Additionally, Elkem holds a 30% interest in and an exclusive marketing agreement with Icelandic Alloys.[11]

In October, Norway's Finance Minister proposed an increase in the electricity tax to be applied to all consumers at a uniform rate, from 0.37 cent to 0.39 cent per kilowatt hour, effective in 1986. Norwegian ferrosilicon producers had sought some reduction in the electricity tax because of the depressed state of the ferrosilicon market.

**Pakistan.**—Saadi Ferroalloys Inc. planned to set up a plant to produce about 16,000 tons per year of 75% ferrosilicon. The new facility will be built in the North-West Frontier Province in the Hazera District.[12]

**South Africa, Republic of.**—Silicon Smelters Ltd., a subsidiary of South African Manganese Amcor Ltd., planned to expand silicon metal production by about 26,000 tons at its Witkop plant in Transvaal, over a period of 4 years. A new 13,000-ton-per-year furnace was expected to come on-line in 1987, with a second furnace scheduled for installation 2 years later. The company's expansion plans were based on forecasts of high growth in demand for silicon metal by the chemical industry and a more moderate increase in consumption by the secondary aluminum sector.[13]

Electricity costs for ferroalloys producers in the Republic of South Africa were raised by 10% on September 1, bringing the total increase for the year to 15%.

**Spain.**—Sociedad Española de Carburos Metálicos S.A. planned to invest about $19 million in the construction of a hydroelectric project at Santa Eugenia in Galicia. The company expected to improve its power consumption efficiency by this undertaking. Carburos Metálicos produces 75% ferrosilicon and other ferroalloys.[14] The Asociación Técnica Española de Fundición requested that a special quota be set up for the duty-free import of about 2,600 tons of magnesium ferrosilicon.

**Sweden.**—Uddevalla Kiselmetalverk AB, a joint venture formed by HB-Consult and Skanska Cement, planned to build a 33,000-ton-per-year silicon metal plant in Uddevalla. The plant was scheduled to come onstream in early 1988. The facility's overall production costs were expected to be low since waste heat from the furnaces will be purchased by the Uddevalla'a district heating system.[15]

Malmo Industrikombinat AB, also jointly owned by HB-Consult and Skanska Cement, planned to build a 55,000-ton-per-year ferrosilicon plant at Swede Harbour, Malmo. Construction was scheduled to begin in April 1986, with startup of the plant planned for 1988. Power costs for the facility will be partially offset by the sale of waste heat from the furnaces to the Malmo municipality.[16]

**Venezuela.**—C.V.G. Ferrosilicio de Venezuela C.A.'s (FESILVEN) output of ferrosilicon reportedly was expected to be about 54,000 tons in 1985, compared with about 42,000 tons in 1984. FESILVEN's production fell to a very low level in the first half of 1984 owing to an explosion in one of the company's two furnaces, which put the plant out of operation for several weeks. The company has a nominal capacity of about 60,000 tons of ferrosilicon per year, most of which is exported to Europe, Japan, and the United States.[17]

## TECHNOLOGY

Advanced ceramics, such as silicon carbide, silicon nitride, and sialon (a mixture of alumina and silicon nitride) are attractive because of their unusual resistance to heat, corrosion, and abrasion and wear. These high-performance materials have great potential, provided researchers can learn to design and manufacture ceramic parts in intricate shapes that are less brittle than the materials available now. Advanced ceramic materials are unreliable under stress.

U.S. companies such as Air Products & Chemicals Inc., ARCO Chemical Co., Dow Chemical Co., Dow Corning Corp., E. I. duPont de Nemours & Co. Inc., GE, W. R. Grace & Co., Koppers Inc., and Sohio Engineered Materials among others are all expanding the scope of their ceramic programs. Norton Co. and TRW Inc. formed a joint venture, Norton/TRW Ceramics Inc., in October 1985. The new company was formed to develop wear-resistant and hot-section parts for aerospace gas-turbine, rotary, and reciprocating engines that can run at much higher temperatures than metal engine parts can withstand. Heat engines with ceramic parts would be expected to offer substantial energy savings while also reducing automobile emissions.

Sohio Engineered Materials, a division of Sohio Inc., makes a variety of silicon carbide parts including mechanical seals, blast nozzles, fluid control nozzles, semiconductor hardware, and tubing for heat exchangers. General Motors' Allison Turbine Div., under a contract signed with the National Aeronautics and Space Administration's (NASA) Lewis Research Center, Cleveland, OH, is developing a nondestructive, photoacoustic spectroscopy technique to distinguish surface and near-surface ceramic flaws in the 50- to 100-micrometer range. Oak Ridge National Laboratory (ORNL) planned to build a $9.3 million laboratory for high-temperature-materials research. The facility's mission will be to develop ceramics that allow transportation and energy generating equipment to run more efficiently at high temperatures. AiResearch Casting Co. and Garrett Turbine Engine Co., units of Garrett Corp., received a $1.7 million ceramic materials research and development contract by NASA's Lewis Research Center. The NASA contract is the result of AiResearch's past and current fabrication of experimental high-technology ceramics of silicon nitride. Cabot Corp., Boston, MA, signed a letter of intent to purchase the ceramics unit of Augat Inc., Attleboro, MA. Augat produces ceramic packages for integrated circuit computer chips.[18]

Composite materials are coming under intense investigation in response to material requirements for advanced aerospace systems. For high-temperature applications, research efforts include work on ceramic matrix composites (CMC) and metal matrix composites (MMC). The main purpose of fiber reinforcement for MMC is to achieve high-temperature strength-to-density properties greater than those for superalloys. For the CMC, the fibers are introduced mainly to yield lightweight ceramic materials with greater toughness and reliability than conventional monolithic structural ceramics. A wide variety of silicon carbide reinforcements are available. However, evaluation studies by scientists at NASA's Lewis Research Center indicate that available commercial fibers do not meet all the necessary property requirements for providing MMC and CMC with high strength and toughness. Fiber research and development efforts are expected to overcome these limitations. Silicon carbide is available in the form of continuous fibers, short fibers, whiskers, and particles. Silicon carbide in the form of whiskers, short fibers, and particles is being used as a reinforcement of mainly aluminum and its alloys.

Two primary obstacles to achieving CMC with optimum microstructures are the development of high-strength, high-modulus, small-diameter continuous fibers whose mechanical properties are not drastically degraded by CMC processing or use conditions and net shape composite processing methods, that result in uniform microstructure of nondegraded aligned fibers surrounded by low porosity matrices. Major emphasis is being placed on silicon-carbide-based fibers. A recently developed CMC approach that shows promise for yielding high-temperature composites with good toughness and strength is the formation of reaction-bonded silicon nitride matrices reinforced by silicon carbide fibers produced by chemical vapor deposition.

Dow Corning is the prime contractor in a $22 million Defense Advanced Project Research Agency aimed at developing high-temperature ceramic fibers made of silicon carbide and ceramic composites that can withstand temperatures in the range of from 1,200° C to 1,400° C. Several years of research conducted by the U.S. Air Force Aeronautical Systems Division's Flight Dynamics Laboratory, Wright-Patterson Air Force Base, and LTV Corp.'s Aerospace and Defense Division resulted in a successful test firing of a solid rocket motor with a case made of the metal matrix materials, silicon carbide and aluminum. The Air Force is interested in the possibility of replacing the typical aluminum rocket motor casing with another material, mainly to achieve weight savings. Large ceramic composite panels of silicon carbide reinforced with silicon carbide fibers will be used for the heat shield on France's aerospace shuttle. The composite is able to withstand rapid temperature changes far in excess of what either component can tolerate separately.[19]

Photovoltaic systems (solar cells) have not reached the stage of development where they are cost competitive with fossil-fuel electric generating plants. Single-crystal silicon, a costly material, is the dominant material from which solar cells are made. Scientists are showing increased interest in amorphous silicon, which can be produced at a much lower price than single-crystal silicon, as an alternative in the manufacture of solar cells. To make amorphous silicon solar cells, very thin films of amorphous silicon are deposited on stainless steel or glass substrates. Although amorphous silicon solar cells are less efficient than single-crystal cells, they are much less expensive and easier to mass produce.

Sovonics Solar Systems, a joint venture partnership of Energy Conversion Devices (ECD), Troy, MI, and Standard Oil Co. of Ohio, reported having achieved an energy conversion efficiency of 12.2% in the laboratory for its amorphous silicon cells. Sovonics' cells consist of three extremely thin, vertically stacked subcells, each of which is sensitive to a different color in the spectrum.[20] Sandia Base Laboratories, Albuquerque, NM, developed a process that increases the electrical efficiency of polycrystalline silicon to 14.5% by exposing the material to a beam of hydrogen ions in a vacuum chamber. Mobil Solar Energy Corp., Waltham, MA, and Solavolt-Motorola Inc., Phoenix, AZ, are currently developing prototype solar cells using the hydrogen-treated polycrystalline material. Southern Co., an electric utilities company based in Atlanta, GA, invested $6.1 million for an 85% share in a new solar cell manufacturing plant in Birmingham, AL. The plant will be jointly owned with Chronar Corp., Lawrenceville, NJ, a maker of amorphous silicon cells.[21]

Union Carbide's new technology to make polycrystalline silicon employs silane ($SiH_4$) as an intermediate product instead of trichlorosilane ($HSiCl_3$), which is used in the conventional process. In Union Carbide's process, silicon tetrachloride ($SiCl_4$) is hydrogenated to trichlorosilane in a fluidized bed of metallurgical silicon at 932° F and 515 pounds per square inch, followed by catalytic conversion into silane. The silane is then pyrolyzed, yielding very-high-purity polycrystalline silicon.[22]

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# Silver

### By Robert G. Reese, Jr.[1]

Domestic mine production of silver declined in 1985 as the silver price continued the downward trend begun in 1983, and mining companies emphasized financial results improvement. Exploration declined except at those prospects that contained gold as the main product. Correspondingly, most new silver production was from new gold mines with byproduct silver. World mine output of silver was unchanged, owing in part to production from new mines, to enhanced mining profits brought about by currency devaluations relative to the U.S. dollar, and to the need by some silver exporting countries to earn foreign exchange.

U.S. silver consumption remained at about the same level as in 1984 and 1983. Silver consumption by all market economy countries was estimated to have increased by 11 million ounces.[2]

**Domestic Data Coverage.**—Domestic mine production data for silver are developed by the Bureau of Mines from four separate voluntary surveys of U.S. operations. Typical of these surveys was the lode-mine production survey of gold, silver, copper, lead, and zinc. Of the 140 lode silver operations to which a survey form was sent, 87% responded, representing 97% of the

**Table 1.—Salient silver statistics**

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Mine production thousand troy ounces | 40,683 | 40,248 | [r]43,431 | [r]44,592 | 39,357 |
| Value thousands | $427,922 | $319,975 | [r]$496,850 | [r]$362,976 | $241,653 |
| Percentage derived from: | | | | | |
| Precious metals ores | 54 | 68 | 76 | 80 | 70 |
| Base metal ores | 46 | 32 | 24 | 20 | 30 |
| Placers | (1) | (1) | (1) | (1) | (1) |
| Refinery production: | | | | | |
| Domestic and foreign ores and concentrates thousand troy ounces | 47,007 | 44,170 | 50,450 | [r]50,019 | 45,609 |
| Secondary (old scrap) do | 39,067 | 27,171 | 25,549 | 24,070 | 24,285 |
| Exports: | | | | | |
| Refined do | 15,131 | 12,876 | 13,658 | 10,340 | 12,611 |
| Other do | 12,772 | 12,594 | 18,294 | 14,108 | 12,145 |
| Imports for consumption: | | | | | |
| Refined do | 75,921 | 96,917 | 161,199 | 93,546 | 137,398 |
| Other do | 18,194 | 20,541 | 18,692 | 21,420 | 15,204 |
| Stocks, Dec. 31: | | | | | |
| Industry do | 20,875 | 20,467 | 17,536 | 21,173 | 17,136 |
| Futures exchanges do | 96,511 | 106,182 | 151,232 | 137,631 | 173,144 |
| Consumption: | | | | | |
| Industry and the arts do | 116,670 | 118,840 | 116,464 | 114,841 | 118,559 |
| Coinage do | 179 | 1,846 | 2,128 | 2,665 | 355 |
| Price, average per troy ounce[2] | $10.52 | $7.95 | $11.44 | $8.14 | $6.14 |
| Employment[3] | 3,600 | 2,900 | 2,400 | 2,600 | [p]3,000 |
| World: | | | | | |
| Mine production thousand troy ounces | [r]361,617 | [r]382,969 | 392,054 | [p]415,239 | [e]412,273 |
| Consumption:[4] | | | | | |
| Industry and the arts do | [r]344,000 | [r]351,800 | [r]349,600 | [r]362,900 | 373,900 |
| Coinage do | 9,000 | 12,800 | [r]19,600 | [r]8,700 | 8,700 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Less than 1/2 unit.

[2] Handy & Harman.

[3] Mine Safety and Health Administration.

[4] Market economy countries only. Source: Handy & Harman.

total U.S. mine production shown in tables 1, 2, 3, 5, 6, and 7. Production for the remaining 18 firms was estimated using prior reported production levels adjusted for economic trends and for information from other sources, such as company annual reports, news or journal articles, or State agency reports.

**Legislation and Government Programs.**—On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, silver would be categorized in tier II, and the goal would be 87.5 million ounces. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

On July 9, the President signed Public Law 99-61, the Statue of Liberty-Ellis Island Commemorative Coin Act, authorizing the U.S. Mint to produce 500,000 gold, 10 million silver, and 25 million cupronickel coins commemorating the centennial of the Statue of Liberty. Each silver coin would contain 0.77 ounce of silver. Title III of Public Law 99-61 authorized the production of a silver bullion coin upon completion of the Statue of Liberty coin program. The bullion coin would have a $1.00 face value, contain 1 ounce of 999 fine silver, and be produced in quantities sufficient to meet demand. Silver for both the Statue of Liberty coin program and the bullion coin program was to be obtained from the silver held in the National Defense Stockpile.

## DOMESTIC PRODUCTION

Silver production was reported at 113 mines, including 12 placer operations. Silver was produced from precious metal ores at 71 mines while 30 mines produced silver as a byproduct of the processing of copper, lead, and zinc ores. The 25 largest mines accounted for 95% of total domestic mine output. In 1985, 10 mines each produced more than 1 million ounces of silver, which when aggregated equaled 76% of the total domestic production.

For the past several years, the mining industry's emphasis regarding silver has been on the discovery and development of new deposits, owing in part to the historic high silver price in 1979-80, and to the relative strength of the silver price when compared with the prices of base metals such as copper, lead, and zinc. However, 1985 was a year of change for the domestic silver mining industry. As the silver price continued the decline begun in 1983, and the silver market remained oversupplied, return-on-investment became the main concern at many silver producing operations. Many companies reduced their exploration activities during 1985, especially at those byproduct silver projects that did not have gold as the main product. Labor concessions, both in terms of wages and job content, along with operational and organizational changes to improve productivity were used at a number of mines to reduce operating costs and improve profitability. Other companies reduced or eliminated the book value of unprofitable mining assets, or temporarily closed mines, or gave the ownership of mining assets to their shareholders through the creation of new companies in order to improve their operating results.

Battle Mountain Gold Co. was created in 1985 by Pennzoil Co. as a means of transferring ownership of Pennzoil's mining activities to its shareholders, who could if desired use the stock market to dispose of their interest in these mining assets while maintaining their interest in Pennzoil's other assets. Included in Battle Mountain were substantially all of the domestic gold and silver mining and milling operations of Pennzoil's Duval Corp. subsidiary, and Pennzoil's interest in various domestic and Australian exploration and development activities. Pennzoil's Board of Directors approved the tax-free distribution of Battle Mountain's stock to Pennzoil shareholders on June 11. On August 2, each Pennzoil shareholder received one share of Battle Mountain common stock for each Pennzoil share held, at which time Battle Mountain became a separate publicly held corporation.

Similarly, Amoco Corp. gave the ownership of its mining subsidiary, Amoco Minerals Co., to its shareholders on July 1. Each Amoco Corp. shareholder of record on June 19 received 1 share of the new company, Cyprus Minerals Co., for each 10 shares of Amoco Corp. stock held. In 1985, Cyprus Minerals produced 625,000 ounces of silver, primarily from its Bagdad and Thompson Creek Mines.[3]

St. Joe Minerals Corp., a subsidiary of Fluor Corp., transferred all of its domestic, Chilean, and Canadian precious metal assets to a new subsidiary, St. Joe Gold Corp., in November. St. Joe Minerals planned an initial public offering equivalent to 6% to 10% of the common stock in St. Joe Gold near yearend. In mid-1985, Freeport-McMoRan Inc. publicly sold common stock equivalent to about 11% of the ownership of its Freeport-McMoRan Gold Co. subsidiary.

**Alaska.**—Commercial production began at the Grant Mine in November. Joint developers of the gold-silver operation were Silverado Mines Ltd., Aurex Inc., and Tri-Con Mining Inc. with holdings of 55%, 40%, and 5%, respectively. A 230-short-ton-per-day mill at the mine recovered precious metals using flotation and cyanidation. Reserves were estimated at 591,000 short tons grading 0.61 ounce of gold per ton. In late December, the mine temporarily closed, reportedly because of lower than expected operating results.

The Alaska State Legislature passed a measure allowing the Alaska Industrial Development Authority to issue up to $175 million worth of bonds to provide funds for construction of port facilities on the Chukchi Sea and a road from the port to the Red Dog lead-zinc-silver deposit. Federal legislation was enacted in October allowing the road to be constructed through the Cape Krusenstern National Monument.

An informal survey of Alaskan silver producers by the Alaska State Division of Geological Geophysical Survey indicated that 28,500 ounces of silver was produced in Alaska during the year, compared with about 5,000 ounces reported to the Bureau of Mines on a voluntary basis by producers.

**Arizona.**—Cyprus Minerals reduced the book value of the Bagdad Mine, a copper-molybdenum-silver-gold operation, by $194.8 million to $189.2 million. Low metal prices and an unfavorable finding in a study of Cyprus Minerals' ability to recover the carried value of its Bagdad investment were cited as the reasons for writing-down Bagdad's book value. The Bagdad Mine achieved full production in January 1985 following a 9-month closure in 1984 during which operating costs at the mine were reduced.

In September, ASARCO Incorporated acquired the Pima Mine, a copper-silver producer, from Cyprus Pima Mining Co., for $12.5 million payable over a 10-year period. The Pima Mine operated in the same pit as Asarco's Mission, Eisenhower, and San Xavier Mines. Acquisition of Pima resulted in a near 30-million-ton reserve increase at the Mission complex, to over 286 million tons with an average grade of 0.62% copper and 0.13 ounce of silver per ton. The acquisition was expected to allow more efficient operations in the pit. Asarco reported that its 1985 share of silver production from the Mission complex was 1.07 million ounces contained in concentrates.[4]

In November, all remaining operations at the Twin Buttes Mine were terminated. About 160 employees were affected. Anamax Mining Co., operator of the copper-silver-molybdenum mine, had halted mining operations in January 1983, but had continued to operate a copper oxide leach plant on the property. The last reported silver production for Twin Buttes was 392,000 ounces in 1983.[5]

**Colorado.**—Homestake Mining Co. temporarily closed the Bulldog Mine on January 29, 1985, owing to depressed silver prices. In 1984, the silver-lead mine was Colorado's largest silver producer. Although mine operations remained suspended throughout the remainder of the year, the carbon-in-pulp plant continued to operate, recovering gold and silver from loaded carbon from the Homestake Mine in South Dakota. It was estimated that 90 employees were affected by the closure.

Standard Metals Corp. closed the Sunnyside Mine during the first quarter of 1985. Low gold and silver prices were cited as the primary reasons for the closure. Sunnyside was the second largest silver producing operation in Colorado in 1984. Standard Metals, operating under Chapter 11 of the Federal Bankruptcy Code, agreed to sell the Sunnyside Mine to Echo Bay Mines Ltd. for $20 million plus other interests. Following approval of the sale by the U.S. Bankruptcy Court for the District of Colorado in late October, Echo Bay acquired the mine in November. Echo Bay subsequently began to refurbish the mine for a planned mid-1986 reopening.

Leadville Corp. assumed the costs of

maintaining the Sherman Mine on February 1, 1985, as stipulated in the 1984 agreement between Hecla Mining Co. and Leadville, which allows Leadville to purchase Hecla's 50-year operating lease of the mine for $1.5 million. Hecla subsequently extended the deadline for payment of the $1.5 million from December 31, 1985, to June 30, 1986. The Sherman Mine remained closed throughout 1985.

Asarco reported that 344,000 ounces of silver in concentrate was produced at its Leadville Unit.[6] In 1984, 363,000 ounces was produced.

**Idaho.**—In July 1985, NERCO DeLamar Co., a subsidiary of NERCO Inc., acquired Superior Oil Co.'s 47.5% interest in the DeLamar Mine, giving NERCO total ownership. Mine production at DeLamar was 1,557,000 ounces of silver and 28,000 ounces of gold.[7] Reserves at DeLamar were increased through exploration to 11.09 million tons grading 1.84 ounces of silver and 0.23 ounce of gold per ton.

At the Lucky Friday Mine, a record high 276,817 tons of ore was milled during 1985, compared with 257,315 tons in 1984.[8] Silver production was 4,740,971 ounces in 1985, a decrease of nearly 55,000 ounces from production in 1984. Despite the drop in silver output, productivity increased by 20%, owing in part to reduced employment and to mine and mill improvements. Hecla began testing a new mechanized mining method at Lucky Friday, which, if successful, should result in improved mine efficiency and safety.

Sunshine Mining Co. announced in January the closure of some low-grade stopes at the Sunshine Mine. An estimated 35 employees were affected by the decision. Production at the Sunshine Mine was 4,714,403 ounces of silver from 218,496 tons of ore, compared with 4,808,072 ounces in 1984.[9] Exploration and development activities continued in 1985, although at a lower rate than in previous years, owing in part to the lower silver price.

At Sunshine's refinery, 3,034,256 ounces of silver and 21,384 ounces of gold were produced from concentrates from the Sunshine and Sixteen-to-One Mines.[10] On December 13, Sunshine acquired the refining and minting equipment of Tentex Inc., a California-based precious metals reclamation and custom minting operation. Sunshine planned to move this equipment to Idaho. With this purchase, Sunshine completed the vertical integration of its precious metals operations, and thus could control its silver production from the mining of ore to the minting of bullion coins. Sunshine Bullion Co., a Sunshine subsidiary, reported sales of 4 million ounces of silver to the public in the form of bullion coins, bullion bars, and jewelry.

Bunker Limited Partnership closed some marginal underground workings at the Crescent Mine during the first quarter of 1985. At the Coeur Mine, Asarco reported the production of 2.6 million ounces of silver in concentrate, compared with 2.5 million ounces in 1984. At the Clayton Mine, 261,931 ounces of silver was recovered from 102,258 tons of ore in 1985, an increase of over 42,000 ounces from that of 1984. Silver production at the Galena Mine, operated by Asarco, declined in 1985 to 4.1 million ounces in concentrate from 4.2 million ounces in 1984.

**Missouri.**—Ore production at the Buick lead-zinc-silver mine improved from 1.5 million tons to about 2.3 million tons mined and milled in 1985. The production increase was the result of an agreement that ended a strike lasting from May 31 to December 29, 1984, by the mine's unionized workers. A significant reduction in Buick's reserves followed a decision by AMAX Inc., the mine operator, to revise Buick's mining plans. Reserves were reduced to 20 million tons, grading 8.0% lead and 2.2% zinc, from 36.1 million tons, grading 5.6% lead and 1.4% zinc.[11]

A record high 1.15 million tons of ore was produced at the Magmont Mine, a lead-zinc-silver operation, during 1985.[12] Productivity improved to 26.9 tons per worker shift owing to increased mining efficiency and increased mill throughput following replacement of the original flotation cells with large-volume cells.

Production began at Asarco's West Fork lead-zinc-silver mine in September. The mine was operating at about 40% of capacity by yearend. Reported production for the year was 2,000 ounces of silver, 3,900 tons of lead, and 100 tons of zinc, in concentrate.[13]

**Montana.**—Pegasus Gold Inc. acquired Wharf Resources Ltd.'s interest in the Landusky Mine for cash and warrants to purchase common shares in Pegasus. The transaction gave Pegasus total ownership of the gold-silver mine, which prior to the acquisition Pegasus had operated under a lease from Wharf. There was no production at Landusky in 1985 because of extensive planning required following the discovery and acquisition of substantial new reserves in 1984.

At the Zortman Mine, Pegasus produced 157,500 ounces of silver and 60,400 ounces of gold.[14] On March 20, Pegasus reached an agreement, subject to Gold Reserve Corp. shareholder approval, to acquire Gold Reserve's interest in the Zortman Mine in exchange for Pegasus' common shares. The agreement, if approved by Gold Reserve shareholders in 1986, would give Pegasus total ownership and control of the property.

Asarco reported that 3.6 million ounces of silver in concentrate was produced at the Troy Mine compared with 4.3 million ounces in 1984.

**Nevada.**—Production resumed at the Buckhorn Mine in March following a 4-month shutdown to modernize the ore handling and crushing facilities. The project increased capacity by 30%. In 1985, 600,000 tons of ore was milled to produce over 100,000 ounces of silver, compared with 10,000 ounces of silver from 194,000 tons of ore in 1984. Employment at the mine increased from 36 at yearend 1984 to 66 at yearend 1985.[15]

At the Fortitude Mine, 222,000 ounces of gold and 647,000 ounces of silver were produced.[16] The drilling program on the property resulted in an 18% increase in reserves. Reserves at Fortitude contain an estimated 1.6 million and 2.2 million ounces of recoverable gold and silver, respectively. The Surprise deposit, which Battle Mountain plans to develop as a satellite operation to the Fortitude Mine, was discovered by the Fortitude drilling program. Production from the Surprise deposit was expected to begin in 1987.

In February 1985, operations at the Gooseberry Mine were reduced from 10,000 tons per month to 1,200 tons per month owing to low precious metals prices. Production was maintained at the reduced level until November, when production was halted because of continued low prices and disappointing exploration results. During the year, 25,000 tons of ore was milled yielding an average of 0.182 ounce of gold and 7.87 ounces of silver per ton.[17]

Echo Bay acquired a 50% interest in the Round Mountain Mine on January 1, through the purchase of Copper Range Co. from The Louisiana Land and Exploration Co. Echo Bay subsequently reduced operating costs at the gold-silver heap-leach operation by lengthening the leach cycle, using higher leaching piles, using heated leaching solution in winter, and by pressure stripping of loaded carbon.

AMAX began construction at the Sleeper deposit, in northwestern Nevada. Production from a central high-grade zone containing 1.4 million tons of ore grading 0.324 ounce of gold and 0.903 ounce of silver per ton was expected in mid-1986.

Limited production resumed at the Victor Mine in the second half of 1985. Testing of the mine's facilities following renovations and expansion projects, completed since the mine's closure in 1984, was conducted during this period of production.

At the Candelaria Mine, 2.5 million ounces of silver was produced in 1985.[18] United Mining Corp. closed its New Savage Mine in April because of low gold and silver prices. The New Savage Mine is on the famous Comstock Lode. The Taylor Mine, one of Nevada's largest silver producers, remained closed throughout the year.

**Utah.**—Kennecott closed the Bingham Canyon Mine, a copper-gold-silver operation, in March reportedly because of low prices. During the third quarter, Kennecott announced the purchase of the Carr Fork Mine's reserves from Atlantic Richfield Co.'s Anaconda Minerals Co. subsidiary. The Carr Fork Mine is on property adjacent to Bingham Canyon. Near yearend, Kennecott's parent company, Standard Oil Co., announced a $400 million program to modernize Bingham Canyon. The projects were expected to be completed in 1988.

At the Escalante Mine, nearly 2.4 million ounces of silver was produced in 1985, an increase of over 203,000 ounces from that of 1984.[19] Operating costs at the mine were reduced through an 8% labor force reduction. Additional ore was developed on the southernly extension of the vein, and the possible presence of another vein north of the present mine boundary was indicated in drilling results.

Texaco Inc. sold its Getty Gold Co. subsidiary to Barrick Resources Corp. near midyear. Getty operated the Mercur Mine, a gold-silver operation in southern Utah.

**Washington.**—Asamera Minerals (U.S.) Inc. and Breakwater Resources Ltd. began commercial production at the Cannon Mine in 1985. The mine began operations on January 1, and the mill officially began production on July 15. Nearly 150,000 tons of gold-silver ore was processed. By yearend, mill throughput was averaging 1,600 tons per day. Tenneco Minerals Co. and United Mining sold their properties adjacent to the

Cannon Mine to Asamera and Breakwater for $12.5 million plus royalty and/or net profit interests. The properties sold by Tenneco and United Mining were estimated to contain 600,000 and 1,500,000 ounces of recoverable gold and silver, respectively.

Silver production at the Republic Mine increased to 101,521 ounces from 80,967 ounces in 1984.[20] Development work at the mine encountered two veins, which may contain 300,000 tons of ore, and could extend the mine's life by nearly 5 years at 1985 production rates.

**Other States.**—Handy & Harman opened a new secondary refinery in South Windsor, CT. The plant will process low-grade precious metal-bearing electronic scrap.

Production began at the Ropes gold mine, in Michigan, near yearend. Commercial production was lower than anticipated in part because of unstable wall conditions and localized faulting. A renovated iron ore mill treated 154,000 tons of ore, including 87,000 tons of development ore, during 1985. Average ore grade was 0.067 ounce of gold and 0.179 ounce of silver per ton.[21]

Echo Bay sold the White Pine copper-silver mine to Northern Copper Co., an investment group consisting predominantly of former White Pine employees and management, in the fourth quarter. Echo Bay acquired the Michigan mine, as part of the assets of Copper Range, which Echo Bay purchased from Louisiana Land and Exploration earlier in the year. The White Pine Mine, closed in 1982, was reopened by Northern Copper on November 1, 1985.

In October, AMAX announced that it would phase out smelting and refining operations at its Carteret, NJ, facility, owing to continuing losses and a poor outlook for secondary smelting and refining activities in the United States. Approximately 9.7 million ounces of silver was produced at Carteret from either purchased or toll-refined material during 1985.

Workers struck St. Joe Minerals' Balmat and Pierrepont Mines, in New York, on July 22. Although the strike continued through yearend, the mines were operated at partial capacity by salaried and some nonunion personnel.

Production at Asarco's Amarillo, TX, refinery was reported as 42.3 million ounces of silver, a decrease of about 4.1 million ounces from the 1984 output.[22]

## CONSUMPTION AND USES

Overall silver consumption remained at about the same level as in 1984 and 1983. Silver consumption for photographic materials and in electrical and electronic products increased somewhat, reflecting the continued growth of the U.S. economy and lower silver prices. Stagnant consumption in most end uses may have been due to the continued use of more efficient manufacturing processes and substitutes developed during periods of higher prices, or to changes in consumer tastes, or to the availability of more financially liquid lower premium alternatives to holding silver as an investment.

## STOCKS

Refiner, fabricator, and dealer stocks declined from 21.2 million ounces at yearend 1984 to 15.6 million ounces at the end of the 1985 third quarter. The decline in industrial stocks was probably due in part to the combination of a weak silver price and expectations of future price declines, which prompted stockholders to delay purchases, and to the increase in industrial consumption. In the fourth quarter, as the silver price declined to less than $6.00 per ounce, industrial stocks increased slightly, to 17.1 million ounces at yearend.

Silver depository stocks held by Commodity Exchange Inc. (COMEX) declined to 104.2 million ounces by the end of May, a 14.3-million-ounce decrease from yearend 1984 levels. By the end of June, however, COMEX stocks increased significantly to 132.4 million ounces, and continued to increase thereafter, ending the year significantly higher than in 1984. The depository stocks held by the Chicago Board of Trade (CBT) declined from yearend 1984 levels to 13.9 million ounces at the end of April 1985. CBT stocks increased later in the year, but at yearend 1985 were 17.8 million ounces, compared with 19.1 million ounces at yearend 1984.

## PRICES

Although the domestic silver price, as quoted by Handy & Harman, remained in a relatively narrow range when compared with the volatile prices of the past several years, it continued along the downward trend begun in mid-1983. The most significant price movement occurred from mid-February 1985 through the end of March. The price began the year at $6.14 per ounce, was $5.83 at yearend, and averaged $6.14 for the year. U.S. currency exchange rates, crude oil prices, the U.S. economic outlook, and the potential returns on alternative investments were the major factors in silver price movements, according to analysts.

As with the Handy & Harman silver price, movement of the London spot price occurred within a relatively narrow range, and in general continued along the downward trend begun in mid-1983. The London spot price as quoted by Metals Week began 1985 at $6.25 per ounce. The low for the year of $5.45 occurred on February 25, after which the price increased, reaching the peak of $6.75 on April 15. During the remainder of 1985, the price gradually declined, ending the year at $5.80. The average price for the year was $6.13.

The Union Bank of Switzerland, the Swiss Bank Corp., and Credit Suisse, the three major banks of Switzerland, began publication of a silver price in December to compete with the price established by the London Metal Exchange. The yearend price established by these banks was $5.80.

Futures contracts representing 24.1 billion ounces of silver were traded on COMEX, a decrease of 9.6 billion ounces from the volume traded in 1984. The silver trading volume at the CBT declined by nearly 900 million ounces to 1 billion ounces in 1985. During the year, the CBT received permission from the Commodity Futures Trading Commission to trade options on its silver futures contract. Options trading began on March 29. Each option entitled the holder to either buy or sell one CBT futures contract representing 1,000 ounces of silver at a given price for a specified period of time. Silver futures trading on the Mid-America Commodity Exchange increased to 62 million ounces from 32 million ounces in 1984.

On October 3, 1985, an article in the Wall Street Journal reported that the Hunt brothers had disposed of most of their silver holdings. It was estimated that most of the sales took place over a 9-month period, and may have amounted to 54 million ounces of silver.[23]

## FOREIGN TRADE

U.S. silver exports remained essentially unchanged in 1985, probably owing in part to the continued strength of the U.S. dollar throughout most of the year. A strong dollar, depending upon currency exchange rates, tended to cause silver purchased in the United States to be relatively more expensive than silver from other sources. Canada and Japan remained the largest recipient countries for U.S. silver, most of which was in the form of refined bullion. Exports of refined bullion to Canada increased by 1.1 million ounces; the increase may have been related to the increased participation of Canadian companies in the U.S. mining industry. Exports of refined bullion to Japan declined by nearly 600,000 ounces.

U.S. silver imports for consumption increased by one-third, in part owing to increased industrial consumption and the strong U.S. dollar. The most significant increases in silver imports into the United States came from the United Kingdom, with an increase of 18.8 million ounces; Belgium-Luxembourg, with an increase of 11.0 million; Switzerland, with an increase of 9.8 million; and Canada, with an increase of 9.2 million. Most of the increased imports from these countries consisted of refined bullion: the United Kingdom, 18.9 million ounces; Belgium-Luxembourg, 9.5 million ounces; Switzerland, 9.8 million ounces; and Canada, 8.7 million ounces. U.S. silver imports from Peru declined substantially.

Imports for consumption of ore and concentrates declined significantly. Peru, with a decrease of 7.3 million ounces, and Mexico, with a decrease of 1.7 million ounces, were the countries with the largest decreases in ore and concentrate shipments to the United States.

The United States was a net importer of silver. Net import reliance calculated as a percentage of apparent consumption was approximately 60%.

## WORLD REVIEW

Despite the decline in U.S. silver production, world mine production of silver was essentially unchanged, owing in part to production from new mines, especially gold mines that produce byproduct silver, to the continued need by some developing countries to earn foreign exchange for debt repayment, and to the strong U.S. dollar, which moderated the impact of the declining silver price on foreign earnings. Exploration continued to be very active for gold deposits; however, exploration for other sources of byproduct silver, such as copper, lead, or zinc deposits, or for primary silver deposits was limited. Australia, Canada, Mexico, and Peru continued to be the countries where most of the silver-bearing discoveries were reported, although there appeared to be increasing interest in exploring the islands of the Pacific Basin for precious metals deposits.

Total consumption of silver by market economy countries was estimated at 382.6 million ounces, an increase of 11 million ounces over the revised figures for 1984. Of the 382.6 million ounces consumed, 373.9 million was used in industrial applications, an increase of 11 million ounces over the 1984 level. The quantity of silver used for coinage, 8.7 million ounces in 1985, was the same as the revised estimate for 1984.[34]

The total silver required by all market economy countries including the United States for industrial use and coinage, for bullion stocks, and for net exports to centrally planned economy countries exceeded their primary production by 106.3 million ounces. The shortfall was met with silver obtained from the following sources: old scrap, 72.2 million ounces; outflow from stocks held in India, 25.7 million ounces; demonetized coin, 3.0 million ounces; and withdrawals from government stocks, 5.4 million ounces. Estimated net exports to centrally planned economy countries was 1 million ounces.[35]

**Australia.**—Aberfoyle Ltd. reported that over 260,000 tons of ore was produced at the Que River Mine in Tasmania, a 19% increase from that of 1984.[36] Ore grades at the zinc-lead-copper-silver-gold mine were 14.2% zinc, 8.1% lead, 0.4% copper, 7.4 ounces of silver, and 0.1 ounce of gold per ton. During 1985, additional equipment was purchased to expand the mine's capacity to over 330,000 tons per year. Employment at the mine increased to 333 from 315 at yearend 1984.

Development work at Aberfoyle's Hellyer deposit continued. Construction of a 4,000-foot adit for underground exploration of the ore body reached the midpoint by yearend and was expected to reach the ore body in mid-1986. Laboratory testing on drill core samples indicated that flotation would probably be the most practical and economic process for treating the fine-grained polymetallic ore even though achieving any significant gold recovery from the ore would be difficult given the refractory nature of the gold content. Conversion of the nearby Cleveland tin mill to a trial milling facility for Hellyer ore continued and was expected to be completed by mid-1986. The mill was to have a nominal capacity of 11 tons per hour.

The British Petroleum Co. PLC reported that the Teutonic Bore Mine was closed owing to exhaustion of reserves. Silver production increased to nearly 1.14 million ounces from 1.06 million ounces in 1984.

At its Zinc Corporation Mine and New Broken Hill Consolidated Mine, CRA Ltd. reported that 2.46 million tons of ore was produced in 1985, compared with 2.06 million tons in 1984. Both mines were at Broken Hill in New South Wales. CRA decided to close the 47-year-old Zinc Corporation concentrator, and to upgrade the New Broken Hill concentrator so that it could treat the ore from both mines. An agreement was reached with the New South Wales government that would allow the mines to be connected to the New South Wales electricity grid, subsequently allowing the closure of CRA's oil-fired power generating station. The closure of the concentrator and the power station were expected to significantly reduce future operating costs.

Following agreements near yearend 1984, which allowed CRA to buy the interests of its two partners in the Woodlawn Mine, CRA completed the acquisition in early 1985. An exploration program to test the feasibility of extending the mine's life as an underground operation following exhaustion of strippable reserves was begun during 1985. Ore production was 1.03 million tons in 1985.[37]

Production began at the Kidston Mine, a gold operation with byproduct silver, on March 1. The Kidston Mine was operated by Kidston Gold Mines Ltd., a 70%-owned subsidiary of Placer Development Ltd. The mine was operating at design capacity by midyear, and at yearend, mill throughput was averaging 15,300 tons per day. During the first 10 months of operation, 4.16 million tons of ore was milled.[28]

During the fiscal year ended June 30, 1985, about 10.3 million tons of ore was treated at the Mount Isa Mine in Queensland.[29] Increased hoisting capacities and the use of the Jubilee mill heavy-medium plant in the silver-lead-zinc processing stream to increase the rejection of barren material prior to concentrator processing were cited as the major factors in allowing a record-high tonnage of ore to be processed.

M.I.M. Holdings Ltd. agreed to sell its 50% interest in the Lady Loretta deposit to Pancontinental Mining Ltd. on August 22. The deposit, in Queensland, contained silver, lead, and zinc.

**Canada.**—Silver production at Brunswick Mining and Smelting Corp. Ltd.'s No. 12 Mine increased to about 6.8 million ounces in concentrate from about 6.2 million ounces in 1984.[30] Construction of an in-mine crusher and a footwall backfill system was completed in 1985. Both projects were expected to reduce future operating costs. The No. 12 Mine was closed for 2 weeks at yearend owing to a zinc concentrate surplus. At its Smelting Div., Brunswick produced nearly 2,659,000 ounces of doré from 213,000 tons of concentrate, dust, and residues. Smelting Div. output was lower than in prior years owing in part to a January acid plant shutdown for catalyst screening.

At the Sullivan Mine, Cominco Ltd. milled 2,397,000 tons of ore with an average silver content of 1.5 ounces per ton. The mill throughput was less than the 2.73 million tons processed in 1984 because of a decision to reduce metal production at the Trail smelter-refinery complex. Employment at Sullivan declined from 1,125 to 986 at yearend 1985.

The Trail smelter refinery produced about 9.8 million ounces of refined silver, compared with 10.6 million ounces in 1984. Cominco attributed the lower refined silver production to a drop in quantity of lead concentrates with a high silver content that could be purchased by the company. Employment at Trail was reduced to 2,562 from 3,164, through rationalization and reorganization of the work force.

Production costs at the Silvana Mine were reduced following a conversion from diesel to hydropower, according to Dickenson Mines Ltd. The mine produced 470,000 ounces of silver from 25,418 tons of ore.[31]

Newmont Mining Corp. reported that 266,666 ounces of silver was produced from the treatment of 7,585,000 tons of ore at the Similkameen copper mine in British Columbia.[32] The increased mill throughput was attributed to the installation of an intermediate crusher in the grinding circuit during 1985. Silver production at the Fox copper-zinc-silver-gold and Ruttan copper-zinc-silver-gold mines, in which Newmont has a 34% interest, was 165,727 ounces and 304,196 ounces, respectively.

Noranda Inc. reopened the Bell copper-gold-silver and Brenda copper-molybdenum-gold-silver mines. Negotiations with the mines' labor unions and the British Columbia government prior to the reopenings obtained concessions that reduced the mines' operating costs. Silver production at the Bell Mine was 32,000 ounces, and the Brenda Mine produced 80,000 ounces.[33]

Noranda reported that the Geco Mine produced 1,325,000 ounces of contained silver, Mattabi Mines produced 555,000 ounces, and the Lyon Lake Mine produced 1,430,000 ounces. In 1984, these mines produced 1.4 million ounces, 1.2 million ounces, and about 1.9 million ounces of contained silver, respectively. Overall, mines in which Noranda had an interest in 1985 produced 9.8 million ounces of silver, 2.4 million ounces less than in 1984. Noranda reduced employment at its Horne smelter and CCR refinery through a combination of early retirements, layoffs, and attrition.

The Copper Rand mill produced 76,918 ounces of silver from the treatment of 402,922 tons of ore from the Copper Rand Mine, and 54,338 ounces of silver from the treatment of 285,335 tons of ore mined at the Portage Mine.[34] A 4-year expansion program at the Portage Mine was completed, and the mine returned to full capacity in the fourth quarter. Gold recovery at the mill was improved through the addition of a jig and two sluice boxes to the gravity circuit. However, a cyanidation plant installed in 1984-85 remained inoperative, owing to metallurgical problems. Operating costs at the mine and mill were reduced through improved operating efficiencies, mining lower tonnages, elimination of the summer vacation shutdown, and a reduction in employment from 651 to 525.

In October, a project was begun that would increase the mill capacity of the Equity silver mine from 5,800 tons per day to 8,500 tons per day. The project included construction of a second rod mill, construction of a third ball mill, and increased flotation and pumping capacities. Production for 1985 was 4.57 million ounces of silver in concentrate.[35] The mill processed about 2.3 million tons of ore.

At the Beaverdell Mine, Teck Corp. reported that 336,426 ounces of silver was produced, compared with 375,709 ounces in 1984.[36] Average mill throughput was 41,105 tons per day in 1985.

United Keno Hill Mines Ltd. reported the production of 1.3 million ounces of silver contained in lead concentrate.[37] A total of 74,609 tons of ore was milled during 1985. The Elsa Mine was reopened in May, and produced 1,980 tons of ore grading 48.2 ounces of silver per ton. Underground mining was also conducted at the Husky, Husky Central, Husky S.W., and Ruby Mines. Mining was halted at the Ruby Mine in May after production of 600 tons of ore, owing to the exhaustion of all known ore reserves. Average silver grade of the Ruby Mine ore was 25.7 ounces per ton. At the Calumet Pit, 221,200 tons of ore containing an average of 21.5 ounces of silver per ton was mined in 1985.

**Mexico.**—México, Desarrollo Industrial Minero S.A. (MEDIMSA) completed development of its new Rosario silver-zinc-copper-lead mine. At the Charcas Mine, MEDIMSA completed a capacity expansion project, which increased the silver-zinc-copper-lead operation's capacity from 1,400 to 3,800 tons per day. From its 11 mines and 5 metallurgical plants, MEDIMSA produced 22.87 million ounces of silver during 1985, compared with 21.23 million ounces in 1984.[38]

At the Real de Ángeles Mine, silver production increased by 23%, while lead and zinc output increased by 25% and 38%, respectively. Higher mill throughput and better recoveries were cited as the major factors for the increased output. Additional mining equipment was purchased and placed in service so that the increased milling rates could be maintained. Silver output was reported as 11.17 million ounces in concentrate in 1985 compared with 9.04 million ounces in 1984.[39] Ore reserves were increased substantially when it was discovered that mineralization extended below earlier pit designs.

AMAX reported that the mines of Compania Fresnillo S.A. de C.V., Zimapán S.A. de C.V., and Rosario Mexico S.A. de C.V. produced 10.4 million ounces of silver.[40] In 1984, these mines produced 10.3 million ounces. At the Bolanos Mine, 49% owned by Kennecott, 1.6 million ounces of silver was produced in 1985, an increase of 600,000 ounces from that of 1984.[41] Lacana Mining Corp. reported that its 30%-owned Torres mining complex in Guanajuato produced nearly 3.8 million ounces of silver in 1985, and that its 40%-owned Encantada Mining Group in Coahuila produced almost 1.2 million ounces of silver.[42] In 1984, Torres produced 4.2 million ounces, and Encantada, 1.8 million ounces. The reduced production by the Encantada Group was attributed to operational problems.

In May 1985, the Mexican Government granted tax and fiscal aid to Mexican mine operators owing to the peso devaluation and the declining silver price. Under the measure, mine operators would receive tax relief ranging from 10% to 45% on any tax assessed.

**Peru.**—Cía. de Minas Buenaventura S.A. remained Peru's largest privately owned silver producing company with an output of nearly 8.6 million ounces. At the Uchucchacua Mine, a project to increase capacity to 1,000 from 700 tons per day was completed. Production at Uchucchacua consisted of 18,515 tons of lead concentrates containing an average of 206.5 ounces of silver per ton. At the Julcani Mine, 7,801 tons of lead concentrates averaging 238.9 ounces of silver per ton was produced. Buenaventura's subsidiary, Cía. de Minas Orcopampa S.A., produced 6,614 tons of concentrates averaging 426.7 ounces of silver per ton. In December, the International Finance Corp. agreed to provide $10 million of the $30 million estimated cost to expand Orcopampa's capacity to 1,000 tons of ore per day, to construct a hydroelectric plant and other facilities, and for exploration and mine development.

At Empresa Minera del Centro del Perú (Centromín Perú), silver production increased to 14.2 from 13.2 million ounces in 1984. Record-high production of silver contained in concentrate was reported for the Casapalca Mine (4.5 million ounces), the Yauricocha Mine (1.3 million ounces), the Cerro-San Expedito Mine (1.1 million ounces), and the Cobriza Mine (948,000 ounces). In 1984, these mines produced 4.0 million, 1.2 million, 1.1 million, and 843,000 ounces, respectively. Centromín Perú's Cerro-Paragsha and Morococha Mines produced 3.1 million ounces and 2.0 million ounces of silver contained in concentrate in 1985, respectively. At the La Oroya Complex, production of refined silver decreased slightly to 23.2 million from 23.6 million ounces. Feed for La Oroya was provided by Centromín Perú and numerous independent mines during 1984.

Cía. Minera Arcata S.A., Peru's second largest private silver producer, produced 3.5 million ounces of silver at the Arcata Mine, compared with 3.3 million ounces in 1984. At the Caylloma Mine, Cía. Minera Caylloma S.A. produced 2.5 million ounces of silver in 1985, and reduced operating costs by 14%. Cía. Minera Milpo S.A. was able to increase output through production from new mine workings, adoption of new beneficiation techniques, and more efficient complementary services. The increased production at Milpo occurred despite several partial work stoppages due to terrorist attacks and a 26-day strike. The company produced nearly 30,000 tons of lead concentrates and 65,000 tons of zinc concentrates containing 79.6 and 4.2 ounces of silver per ton, respectively. Cía. Minera del Madrigal S.A. produced 357,750 ounces of silver in concentrate by milling 344,744 tons of ore grading 1.4 ounces of silver per ton. The Quiruvilca Mine, operated by Corporacíon Minera Nor Peru S.A. produced 2.0 million ounces of silver in 1985 compared with 1.8 million ounces in 1984. Southern Peru Copper Corp. (SPCC) milled 31.2 million tons of ore from its Toquepala and Cuajone Mines to produce 2.8 million ounces of silver contained in its blister copper. In 1984, SPCC milled 30.3 million tons of ore and produced 2.5 million ounces of silver.

**Other Countries.**—For the year ended October 31, 1985, Cía. Minera Aguilar S.A. milled 636,160 tons of ore to produce 1.4 million ounces of silver contained in lead concentrates at its Aguilar Mine in Argentina. The production was essentially the same as that of 1984. At the Quioma Mine in Bolivia, 131,000 ounces of silver was produced, compared with 52,000 ounces in 1984. St. Joe Gold announced that it would expand the capacity of its El Indio Mine, in Chile, to 2,100 tons per day from 1,800 tons per day. For the year ended October 31, 1985, El Indio produced nearly 1 million ounces of silver contained in either its direct smelting ore or its mill products.

The El Mochito Mine in Honduras produced 2.7 million ounces of silver in concentrate in 1985. Production at the mine was increased to offset declining ore grades and to reduce unit costs. In 1984, 2.6 million ounces of silver was produced.

Depressed copper and silver prices and national economic conditions were cited by Atlas Consolidated Mining and Development Corp. for operating reductions made at some of its properties in the Philippines. On July 5, the Biga concentrator was closed, and operations at the Biga and Carmen Pits reduced. Subsequently, the Carmen concentrator was closed on October 1 for general overhaul and for installation of transportation facilities to bring ore from the Lutopan Mine to the concentrator. At this time, the Biga and Carmen Pits were closed. In December, the Carmen concentrator resumed operation, along with some mining activities at the pits to supplement ore production from Lutopan. With the resumption of processing at the Carmen concentrator, the DAS concentrator was closed. Ore production for 1985 was 17.7 million tons from the Biga and Carmen Pits and 11.3 million tons from the Lutopan Mine. Silver content of the concentrates produced was 311,862 ounces, compared with 452,201 ounces in 1984.[43] At its Masbate Pit, Atlas produced 50,579 ounces of silver, a decrease of over 20,000 ounces from that of 1984. The heap-leaching plant at Masbate, in its first full year of operation, produced 6,146 ounces of silver.

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[1] Physical scientist, Division of Nonferrous Metals.

[2] Ounce as used throughout this chapter refers to the troy ounce.

[3] Cyprus Minerals Co. 1985 Annual Report. 33 pp.

[4] ASARCO Incorporated. 1985 Annual Report. 33 pp.

[5] AMAX Inc. 1985 Annual Report. 37 pp.

[6] Work cited in footnote 4.

[7] NERCO Inc. 1985 10K Report. 32 pp.

[8] Hecla Mining Co. 1985 Annual Report. 33 pp.

[9] Sunshine Mining Co. 1985 Annual Report. 38 pp.

[10] Work cited in footnote 9.

[11] AMAX Inc. 1985 10K Report. 62 pp.

[12] Cominco Ltd. 1985 Annual Report. 37 pp.

[13] Work cited in footnote 4.

[14] Pegasus Gold Inc. 1985 Annual Report. 37 pp.

[15] Work cited in footnote 12.

[16] Battle Mountain Gold Co. 1985 Annual Report. 24 pp.

[17] Asamera Inc. 1985 Annual Report. 55 pp.

[18] Work cited in footnote 7.

[19] Work cited in footnote 8.

[20] Work cited in footnote 8.

[21] Callahan Mining Corp. 1985 10K Report. 27 pp.

[22] Work cited in footnote 4.

[23] Wall Street Journal. Hunts Sold Most of Silver Hoard, Taking Estimated $1 Billion Loss. Oct. 3, 1985, p. 3

[24] Handy & Harman. The Silver Market, 1985. 70th. Annual Report. 26 pp.

[25] Work cited in footnote 24.

[26] Aberfoyle Ltd. 1985 Annual Report. 25 pp.

[27] CRA Ltd. 1985 Annual Report. 60 pp.

[28] Placer Development Ltd. 1985 Annual Report. 43 pp.

[29] M.I.M. Holdings Ltd. 1985 Annual Report. 32 pp.

[30] Brunswick Mining and Smelting Corp. Ltd. 1985 Annual Report. 21 pp.

[31] Dickenson Mines Ltd. 1985 Annual Report. 32 pp.

[32] Newmont Mining Corp. 1985 Annual Report. 54 pp.

[33] Noranda Inc. 1985 Annual Report. 46 pp.

[34] Northgate Exploration Ltd. 1985 Annual Report. 29 pp.

[35] Work cited in footnote 27.

[36] Teck Corp. 1985 Annual Report. 33 pp.

[37] United Keno Hill Mines Ltd. 1985 Annual Report. 20 pp.

[38] Work cited in footnote 4.

[39] Work cited in footnote 27.

[40] Work cited in footnote 5.

[41] The British Petroleum Co. PLC 1985 Annual Report. 64 pp.

[42] Lacana Mining Corp. 1985 Annual Report. 33 pp.

[43] Atlas Consolidated Mining and Development Corp. 1985 Annual Report. 21 pp.

## Table 2.—Mine production of recoverable silver in the United States, by State

(Troy ounces)

| State | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Alaska | 2,372 | 2,080 | 4,123 | W | W |
| Arizona | 8,055,231 | 6,309,327 | 4,491,532 | r4,246,616 | 4,885,310 |
| California | 53,286 | 34,048 | 26,899 | W | 115,478 |
| Colorado | 3,008,994 | 1,934,312 | 2,145,616 | 2,199,888 | 548,696 |
| Idaho | 16,545,648 | 14,830,351 | 17,684,278 | 18,869,186 | 18,827,948 |
| Illinois | W | W | W | W | W |
| Michigan | W | W | -- | -- | W |
| Missouri | 1,837,011 | 2,241,159 | 2,021,343 | 1,401,070 | 1,635,301 |
| Montana | 2,988,810 | 6,168,711 | 5,707,963 | 5,652,847 | 4,009,979 |
| Nevada | 3,039,480 | 3,142,263 | r5,179,394 | 6,477,032 | 4,946,523 |
| New Mexico | 1,632,346 | 804,594 | W | W | W |
| New York | 28,829 | 27,212 | 33,137 | W | W |
| Oregon | 7,487 | -- | 856 | W | -- |
| South Carolina | W | -- | -- | -- | W |
| South Dakota | 55,792 | 26,241 | 62,314 | 50,036 | 63,156 |
| Tennessee | W | W | W | W | W |
| Utah | 2,882,671 | 4,342,333 | 4,566,610 | W | W |
| Washington | 67,390 | W | W | W | W |
| Total | 40,683,173 | 40,248,409 | r43,430,937 | r44,591,671 | 39,357,197 |

rRevised. W Withheld to avoid disclosing company proprietary data; included in "Total."

## Table 3.—Mine production of recoverable silver in the United States, by month

(Thousand troy ounces)

| Month | 1981 | 1982 | 1983r | 1984r | 1985 |
|---|---|---|---|---|---|
| January | 3,062 | 3,643 | 3,101 | 3,774 | 3,425 |
| February | 3,404 | 3,283 | 3,051 | 3,897 | 3,045 |
| March | 3,408 | 4,039 | 3,776 | 4,202 | 3,385 |
| April | 3,314 | 3,733 | 3,681 | 4,027 | 3,207 |
| May | 3,151 | 3,713 | 3,675 | 3,892 | 3,351 |
| June | 3,315 | 3,568 | 3,767 | 3,780 | 3,231 |
| July | 3,577 | 3,090 | 3,588 | 3,576 | 3,234 |
| August | 3,408 | 2,987 | 3,755 | 3,719 | 3,355 |
| September | 3,503 | 3,014 | 3,563 | 3,245 | 2,925 |
| October | 3,795 | 2,889 | 3,408 | 3,662 | 3,847 |
| November | 3,354 | 3,241 | 3,414 | 3,323 | 3,124 |
| December | 3,392 | 3,048 | 4,652 | 3,495 | 3,228 |
| Total | 40,683 | 40,248 | 43,431 | 44,592 | 39,357 |

rRevised.

## Table 4.—Twenty-five leading silver producing mines in the United States in 1985, in order of output

| Rank | Mine | County and State | Operator | Source of silver |
|---|---|---|---|---|
| 1 | Lucky Friday | Shoshone, ID | Hecla Mining Co | Silver ore. |
| 2 | Sunshine | do | Sunshine Mining Co | Do. |
| 3 | Galena | do | ASARCO Incorporated | Do. |
| 4 | Troy | Lincoln, MT | do | Silver-copper ore. |
| 5 | Coeur | Shoshone, ID | do | Silver ore. |
| 6 | Escalante | Iron, UT | Helca Mining Co | Do. |
| 7 | Candelaria | Mineral, NV | NERCO Metals Inc | Do. |
| 8 | DeLamar | Owyhee, ID | NERCO DeLamar Co | Gold-silver ore. |
| 9 | Sixteen-to-One | Esmeralda, NV | Sunshine Mining Co | Silver ore. |
| 10 | Tyrone | Grant, NM | Phelps Dodge Corp | Copper ore. |
| 11 | Sierrita | Pima, AZ | Duval Corp | Do. |
| 12 | Eisenhower | do | Eisenhower Mining Co | Do. |
| 13 | Morenci | Greenlee, AZ | Phelps Dodge Corp | Do. |
| 14 | Buick | Iron, MO | AMAX Lead Co. of Missouri | Lead ore. |
| 15 | Battle Mountain | Lander, NV | Battle Mountain Gold Co | Gold ore. |
| 16 | Bagdad | Yavapai, AZ | Cyprus Bagdad Copper Co | Copper ore. |
| 17 | Ray | Pinal, AZ | Kennecott | Do. |
| 18 | Crescent | Shoshone, ID | Bunker Limited Partnership | Silver ore. |
| 19 | San Manuel | Pinal, AZ | Magma Copper Co | Copper ore. |
| 20 | Magmont | Iron, MO | Cominco American Incorporated | Lead ore. |
| 21 | Leadville | Lake, CO | ASARCO Incorporated | Lead-zinc ore. |
| 22 | Reymert | Pinal, AZ | Nichols Development Corp | Silver ore. |
| 23 | Pinto Valley | Gila, AZ | Pinto Valley Copper Co | Copper ore. |
| 24 | Clayton | Custer, ID | Clayton Silver Mines | Silver ore. |
| 25 | Viburnum 29 | Washington, MO | St. Joe Minerals Corp | Lead ore. |

## Table 5.—Silver produced in the United States, by State, type of mine, and class of ore

| Year and State | Placer (troy ounces of silver) | Lode: Gold ore, Short tons | Lode: Gold ore, Troy ounces of silver | Lode: Gold-silver ore, Short tons | Lode: Gold-silver ore, Troy ounces of silver | Lode: Silver ore, Short tons | Lode: Silver ore, Troy ounces of silver |
|---|---|---|---|---|---|---|---|
| 1981 | 1,839 | 8,758,364 | 754,037 | 1,040,878 | 2,263,535 | 4,538,322 | 19,095,412 |
| 1982 | 2,012 | 13,087,462 | 852,500 | 1,213,247 | 2,769,495 | 5,422,706 | 23,577,319 |
| 1983 | 4,035 | 18,329,722 | 1,146,835 | 1,129,756 | 1,794,753 | [r]7,528,125 | [r]30,079,569 |
| 1984 | [r]1,503 | 24,581,032 | 1,333,227 | 1,587,850 | 2,890,407 | 7,804,144 | 31,328,954 |
| 1985: | | | | | | | |
| Alaska | W | -- | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | W | W | W | W |
| California | W | W | W | W | W | -- | -- |
| Colorado | -- | 811,529 | 69,317 | -- | -- | W | W |
| Idaho | -- | 50,637 | 6,574 | W | W | W | W |
| Illinois | -- | -- | -- | -- | -- | -- | -- |
| Michigan | -- | W | W | -- | -- | -- | -- |
| Missouri | -- | -- | -- | -- | -- | -- | -- |
| Montana | W | W | W | W | W | 40,832 | 231,894 |
| Nevada | W | 12,355,594 | 982,180 | W | W | 2,861,995 | 3,833,760 |
| New Mexico | -- | 914,946 | 7,606 | 2,527 | 14,926 | W | W |
| New York | -- | -- | -- | -- | -- | -- | -- |
| South Carolina | -- | W | W | -- | -- | -- | -- |
| South Dakota | -- | 2,345,704 | 63,156 | -- | -- | -- | -- |
| Tennessee | -- | -- | -- | -- | -- | -- | -- |
| Utah | -- | W | W | -- | -- | 292,000 | 2,430,000 |
| Washington | -- | W | W | -- | -- | -- | -- |
| Total | 6,434 | 26,887,964 | 1,571,730 | 1,043,854 | 2,039,797 | 4,302,681 | 24,012,856 |
| Percent of total silver | (1) | XX | 4 | XX | 5 | XX | 61 |

| Year and State | Lode: Copper ore, Short tons | Lode: Copper ore, Troy ounces of silver | Lode: Lead ore, Short tons | Lode: Lead ore, Troy ounces of silver | Lode: Zinc ore, Short tons | Lode: Zinc ore, Troy ounces of silver |
|---|---|---|---|---|---|---|
| 1981 | 281,939,595 | 13,952,838 | 8,524,045 | 1,839,198 | 561,970 | 28,863 |
| 1982 | 190,713,274 | 9,420,220 | 9,407,482 | 2,244,737 | 713,228 | 27,212 |
| 1983 | [2]171,614,767 | [2]7,344,180 | 8,050,251 | 2,021,346 | 753,044 | 33,137 |
| 1984 | [r][2]166,255,710 | [r][2]6,526,427 | 5,272,047 | 1,723,368 | 923,843 | 61,505 |
| 1985: | | | | | | |
| Alaska | -- | -- | -- | -- | -- | -- |
| Arizona | 129,545,286 | 4,382,734 | -- | -- | -- | -- |
| California | -- | -- | -- | -- | -- | -- |
| Colorado | -- | -- | -- | -- | -- | -- |
| Idaho | -- | -- | -- | -- | -- | -- |
| Illinois | -- | -- | -- | -- | -- | -- |
| Michigan | W | W | -- | -- | -- | -- |
| Missouri | -- | -- | 7,091,945 | 1,635,301 | -- | -- |
| Montana | 2,842,971 | 3,565,927 | -- | -- | -- | -- |
| Nevada | -- | -- | -- | -- | -- | -- |
| New Mexico | W | W | -- | -- | -- | -- |
| New York | -- | -- | -- | -- | W | W |
| South Carolina | -- | -- | -- | -- | -- | -- |
| South Dakota | -- | -- | -- | -- | -- | -- |
| Tennessee | W | W | -- | -- | W | W |
| Utah | W | W | -- | -- | -- | -- |
| Washington | -- | -- | -- | -- | -- | -- |
| Total | 154,658,676 | 9,659,224 | 7,091,945 | 1,635,301 | 949,988 | 28,285 |
| Percent of total silver | XX | 25 | XX | 4 | XX | (1) |

**See footnotes at end of table.**

## Table 5.—Silver produced in the United States, by State, type of mine, and class of ore—Continued

| Year and State | Lode | | | | Total | |
|---|---|---|---|---|---|---|
| | Copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores | | Old tailings, etc. | | | |
| | Short tons | Troy ounces of silver | Short tons | Troy ounces of silver | Short tons | Troy ounces of silver |
| 1981 | 3,186,988 | 2,369,785 | 286,419 | [3]377,666 | 308,836,581 | 40,683,173 |
| 1982 | 2,125,147 | 919,329 | 433,446 | [3] [4]435,585 | 223,115,992 | 40,248,409 |
| 1983 | ([5]) | ([5]) | [6]856,550 | [3] [7]1,007,082 | [r]208,262,215 | [r]43,430,937 |
| 1984 | ([5]) | ([5]) | [6]15,377,223 | [3] [7]726,280 | [r]221,801,849 | [r]44,591,671 |
| 1985: | | | | | | |
| Alaska | -- | -- | -- | -- | -- | W |
| Arizona | -- | -- | W | W | 129,738,370 | 4,886,219 |
| California | -- | -- | -- | -- | 2,364,363 | 115,478 |
| Colorado | W | W | -- | -- | 1,041,194 | 548,886 |
| Idaho | W | W | W | W | 5,655,699 | 18,827,948 |
| Illinois | -- | -- | W | W | W | W |
| Michigan | -- | -- | -- | -- | W | W |
| Missouri | -- | -- | -- | -- | 7,091,945 | 1,686,391 |
| Montana | -- | -- | W | W | 10,412,113 | 4,888,979 |
| Nevada | -- | -- | W | W | 15,402,843 | 4,946,523 |
| New Mexico | -- | -- | 85 | 43 | W | W |
| New York | -- | -- | -- | -- | W | W |
| South Carolina | -- | -- | -- | -- | W | W |
| South Dakota | -- | -- | -- | -- | 2,345,704 | 68,156 |
| Tennessee | -- | -- | -- | -- | W | W |
| Utah | -- | -- | 12,385 | 367 | W | W |
| Washington | -- | -- | -- | -- | W | W |
| Total | ([5]) | ([5]) | [6]4,271,240 | [3] [7]403,570 | 199,206,348 | 39,357,197 |
| Percent of total silver | XX | ([1]) | XX | 1 | XX | 100 |

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.

[1] Less than 1/2 unit.

[2] Includes copper-zinc ore and silver recovered from copper-zinc ore in Tennessee to avoid disclosing company proprietary data.

[3] Includes silver recovered from tungsten ore in California and silver recovered from fluorspar ore in Illinois.

[4] Includes silver recovered from molybdenum ore in Nevada.

[5] In order to avoid disclosing company proprietary data, copper-zinc ore and silver recovered from copper-zinc ore in Tennessee are included in totals for copper ore; and lead-zinc ore and silver recovered from lead-zinc ore in Colorado and Idaho are included in total "Old tailings, etc."

[6] Includes lead-zinc ore in Colorado and Idaho to avoid disclosing company proprietary data.

[7] Includes silver recovered from lead-zinc ore in Colorado and Idaho to avoid disclosing company proprietary data, and includes silver recovered from molybdenum ore in Nevada.

## Table 6.—Silver produced in the United States by cyanidation[1]

| Year | Leaching in vats, tanks, and closed containers[2] [3] | | Leaching in open heaps or dumps[4] | |
|---|---|---|---|---|
| | Ore treated (thousand short tons) | Silver recovered (troy ounces) | Ore treated (thousand short tons) | Silver recovered (troy ounces) |
| 1981 | 4,434,835 | 2,579,957 | 7,413,219 | 2,047,709 |
| 1982 | [r]7,875,468 | [r]5,460,897 | 12,295,132 | 1,384,326 |
| 1983[r] | 9,733,730 | 7,058,108 | 12,727,412 | 2,201,221 |
| 1984[r] | 11,172,695 | 7,752,063 | 18,222,366 | 2,986,172 |
| 1985 | 15,421,903 | 6,819,904 | 14,875,133 | 2,701,360 |

[r]Revised.

[1] May include small quantities recovered by leaching with thiourea, by bioextraction, and by proprietary processes.

[2] Including autoclaves.

[3] May include small quantities recovered by gravity methods.

[4] May include tailings and waste ore dumps.

## Table 7.—Lode silver produced in the United States, by State

| Year and State | Amalgamation | | Cyanidation | | Smelting of concentrates | | | Smelting of ore | | Total ore processed[1] (short tons) | Total silver recovered (troy ounces) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ore treated (short tons) | Silver recovered (troy ounces) | Ore treated (short tons) | Silver recovered (troy ounces) | Ore concentrated (short tons) | Concentrates smelted (short tons) | Silver recovered (troy ounces) | Ore smelted (short tons) | Silver recovered (troy ounces) | | |
| 1981 | 790 | 6 | 11,848,054 | 4,627,666 | 296,500,821 | 7,157,354 | 34,815,156 | 486,916 | 1,238,506 | 308,836,581 | 40,681,334 |
| 1982 | -- | -- | r20,170,600 | r6,845,223 | r202,592,304 | r5,256,331 | r32,719,805 | 353,068 | 681,369 | 223,115,992 | 40,246,397 |
| 1983 | 3,400 | 50 | r22,461,142 | r9,259,329 | r185,513,477 | r4,939,007 | r33,338,651 | 284,196 | r 2829,030 | r208,262,215 | r 243,427,060 |
| 1984 | -- | -- | r29,395,061 | r10,738,235 | r192,253,620 | r4,108,133 | r33,373,850 | 153,168 | 478,083 | r221,801,849 | r44,590,168 |
| 1985: | | | | | | | | | | | |
| Arizona | -- | -- | -- | -- | 129,508,286 | 3,024,066 | 4,382,491 | 230,084 | 502,819 | 129,738,370 | 4,885,310 |
| California | -- | -- | W | W | W | W | W | -- | -- | W | W |
| Colorado | -- | -- | W | W | 257,967 | 38,490 | 506,154 | W | W | 1,041,194 | 548,696 |
| Idaho | -- | -- | W | W | 4,785,159 | 78,202 | 17,058,959 | W | W | 5,655,699 | 18,827,948 |
| Illinois | -- | -- | -- | -- | W | W | W | -- | -- | W | W |
| Michigan | -- | -- | W | W | W | W | W | -- | -- | W | W |
| Missouri | -- | -- | -- | -- | 7,091,945 | 660,069 | 1,635,301 | -- | -- | 7,091,945 | 1,635,301 |
| Montana | -- | -- | W | W | 2,883,803 | 39,298 | 3,797,821 | 610 | 2,869 | 10,412,113 | W |
| Nevada | -- | -- | 14,808,688 | 4,853,312 | 599,080 | 1,577 | 92,086 | W | W | W | W |
| New Mexico | -- | -- | 914,946 | 7,606 | W | W | W | W | W | W | W |
| New York | -- | -- | -- | -- | W | W | W | -- | -- | W | W |
| South Carolina | -- | -- | W | W | -- | -- | -- | -- | -- | W | W |
| South Dakota | -- | -- | 2,345,704 | 63,156 | -- | -- | -- | -- | -- | 2,345,704 | 63,156 |
| Tennessee | -- | -- | -- | -- | W | W | W | -- | -- | W | W |
| Utah | -- | -- | 292,000 | 2,430,000 | W | W | W | W | W | W | W |
| Washington | -- | -- | W | W | W | W | W | -- | -- | W | W |
| Total | -- | -- | 30,297,036 | 9,521,264 | 168,650,998 | 4,540,641 | 29,238,043 | 258,314 | 591,456 | 199,206,348 | 39,350,763 |

r Revised. W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Includes old tailings and some nonsilver-bearing ores not separable, in amounts ranging from 0.04% to 0.12% of the totals for the years listed. Excludes fluorspar, molybdenum, and tungsten ores from which silver was recovered as a byproduct and excludes ores leached for recovery of copper.

[2] Includes some placer production to avoid disclosing company proprietary data.

### Table 8.—U.S. refinery production of silver

(Thousand troy ounces)

| Raw material | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Concentrates and ores: | | | | | |
| Domestic | 44,487 | 43,825 | 50,281 | r49,892 | 45,609 |
| Foreign | 2,520 | 344 | 169 | 126 | -- |
| Total[1] | 47,007 | 44,170 | 50,450 | r50,019 | 45,609 |
| Old scrap | 39,067 | 27,171 | 25,549 | 24,070 | 24,285 |
| New scrap | 44,738 | 37,812 | 41,839 | r45,503 | 48,036 |
| Grand total[1] | 130,812 | 109,153 | 117,838 | r119,592 | 117,931 |

rRevised.

[1] Data may not add to totals shown because of independent rounding.

### Table 9.—U.S. consumption of silver, by end use

(Thousand troy ounces)

| End use[1] | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Electroplated ware | 3,904 | 3,254 | 3,154 | 3,542 | 3,660 |
| Sterlingware | 4,407 | 6,579 | 7,022 | 3,638 | 3,527 |
| Jewelry | 5,368 | 6,260 | 6,885 | 5,773 | 5,779 |
| Photographic materials | 51,025 | 51,769 | 51,827 | 56,322 | 57,895 |
| Dental and medical supplies | 1,709 | 1,688 | 1,532 | 1,569 | 1,485 |
| Mirrors | 581 | 970 | 970 | 970 | 970 |
| Brazing alloys and solders | 7,718 | 7,384 | 5,887 | 5,889 | 5,600 |
| Electrical and electronic products: | | | | | |
| Batteries | 3,803 | 4,167 | 2,800 | 2,671 | 2,470 |
| Contacts and conductors | 26,411 | 27,730 | 26,298 | 25,633 | 27,517 |
| Bearings | 297 | 228 | 170 | 260 | 183 |
| Catalysts | 3,830 | 2,418 | 2,424 | 2,448 | 2,400 |
| Coins, medallions, commemorative objects | 2,622 | 1,832 | 2,979 | 2,564 | 2,514 |
| Miscellaneous[2] | 4,995 | 4,562 | 4,567 | 4,562 | 4,559 |
| Total net industrial consumption[3] | 116,670 | 118,840 | 116,464 | 114,841 | 118,559 |
| Coinage | 179 | 1,846 | 2,128 | 2,665 | 355 |
| Total consumption[3] | 116,849 | 120,686 | 118,592 | 117,506 | 118,914 |

[1] End use as reported by converters of refined silver.

[2] Includes silver-bearing copper, silver-bearing lead anodes, ceramics, paints, etc.

[3] Data may not add to totals shown because of independent rounding.

### Table 10.—Yearend stocks of silver in the United States

(Thousand troy ounces)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Industry | 20,875 | 20,467 | 17,536 | 21,173 | 17,136 |
| Futures exchanges | 96,511 | 106,182 | 151,232 | 137,631 | 173,144 |
| U.S. Department of the Treasury | 38,732 | 36,768 | 34,565 | 31,889 | 32,621 |
| U.S. Department of Defense | 3,810 | 1,750 | 100 | 342 | 460 |
| National Defense Stockpile | 137,500 | 137,500 | 137,500 | 137,500 | 137,500 |

### Table 11.—U.S. silver prices

(Dollars per troy ounce)

| Period | Low | (date) | High | (date) | Average |
|---|---|---|---|---|---|
| 1981 | 7.95 | (Dec. 29) | 16.45 | (Jan. 6) | 10.52 |
| 1982 | 4.88 | (June 21) | 11.21 | (Dec. 29) | 7.95 |
| 1983 | 8.34 | (Nov. 17) | 14.74 | (Feb. 16) | 11.44 |
| 1984 | 6.26 | (Dec. 20) | 10.04 | (March 5) | 8.14 |
| 1985: | | | | | |
| January | 5.60 | (Jan. 7) | 6.37 | (Jan. 31) | 6.10 |
| February | 5.60 | (Feb. 25) | 6.32 | (Feb. 14) | 6.07 |
| March | 5.57 | (Mar. 12) | 6.74 | (Mar. 27) | 6.01 |
| April | 6.16 | (Apr. 24) | 6.72 | (Apr. 11) | 6.46 |
| May | 6.02 | (May 28) | 6.65 | (May 14) | 6.28 |
| June | 6.07 | (June 3) | 6.39 | (June 18) | 6.17 |
| July | 5.90 | (July 3) | 6.36 | (July 29) | 6.10 |
| August | 6.11 | (Aug. 6) | 6.38 | (Aug. 16) | 6.25 |
| September | 5.88 | (Sept. 18) | 6.16 | (Sept. 24, 25) | 6.05 |
| October | 6.03 | (Oct. 1) | 6.33 | (Oct. 3) | 6.19 |
| November | 6.00 | (Nov. 8) | 6.28 | (Nov. 25) | 6.13 |
| December | 5.71 | (Dec. 11) | 6.08 | (Dec. 3) | 5.89 |
| Average | XX | | XX | | 6.14 |

XX Not applicable.

Source: Handy & Harman daily quotation.

## Table 12.—U.S. exports of silver, by country

(Thousand troy ounces and thousand dollars)

| Year and country | Ore and concentrates | | Waste and sweepings | | Doré and precipitates | | Refined bullion | | Total[1] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| 1981 | 213 | 1,510 | 9,746 | 115,106 | 2,813 | 34,474 | 15,131 | 181,380 | 27,903 | 332,470 |
| 1982 | 47 | 368 | 10,937 | 87,644 | 1,610 | 14,756 | 12,876 | 105,977 | 25,470 | 208,748 |
| 1983 | 67 | 554 | 17,231 | 197,996 | 996 | 9,516 | 13,658 | 169,383 | 31,952 | 377,449 |
| 1984 | 1,048 | 8,335 | 12,059 | 102,452 | 1,001 | 9,178 | 10,340 | 86,339 | 24,447 | 206,306 |
| 1985: | | | | | | | | | | |
| Belgium-Luxembourg | 265 | 1,604 | 2,148 | 15,161 | 1 | 12 | 1 | 18 | 2,415 | 16,794 |
| Brazil | -- | -- | 10 | 81 | 22 | 192 | 901 | 6,547 | 933 | 6,820 |
| Canada | 4 | 35 | 2,734 | 17,845 | 242 | 1,577 | 5,702 | 37,450 | 8,682 | 56,907 |
| France | -- | -- | 1,727 | 10,778 | 78 | 610 | -- | -- | 1,805 | 11,388 |
| Japan | -- | -- | 21 | 116 | 204 | 1,624 | 3,578 | 22,475 | 3,803 | 24,215 |
| Spain | -- | -- | 704 | 4,795 | 147 | 869 | 467 | 2,900 | 1,318 | 8,564 |
| Sweden | -- | -- | 1,335 | 8,136 | -- | -- | 55 | 358 | 1,390 | 8,493 |
| United Kingdom | -- | -- | 1,075 | 7,311 | 521 | 1,551 | 1 | 5 | 1,597 | 8,867 |
| Uruguay | -- | -- | 16 | 102 | -- | -- | 1,752 | 11,056 | 1,769 | 11,158 |
| Other | 1 | 11 | 556 | 3,560 | 336 | 3,115 | 153 | 936 | 1,046 | 7,622 |
| Total[1] | 270 | 1,651 | 10,825 | 67,884 | 1,550 | 9,551 | 12,611 | 81,746 | 24,756 | 160,832 |

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## Table 13.—U.S. imports for consumption of silver, by country

(Thousand troy ounces and thousand dollars)

| Year and country | Ore and concentrates |  | Waste and scrap |  | Doré and precipitates |  | Refined bullion |  | Total[1] |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| 1981 | 9,769 | 100,422 | 2,051 | 16,414 | 6,874 | 74,439 | 75,921 | 837,174 | 94,115 | 1,028,450 |
| 1982 | 12,530 | 91,638 | 2,837 | 11,979 | 5,173 | 37,308 | 96,917 | 786,154 | 117,458 | 927,079 |
| 1983 | 13,911 | 145,419 | 1,241 | 13,010 | 3,540 | 39,038 | 161,199 | 1,926,102 | 179,891 | 2,123,569 |
| 1984 | 13,018 | 105,587 | 908 | 7,871 | 7,499 | 64,901 | 93,546 | 784,838 | 114,966 | 963,198 |
| 1985: |  |  |  |  |  |  |  |  |  |  |
| Belgium-Luxembourg | 37 | 200 | 1 | 5 | 1,541 | 11,624 | 9,477 | 62,715 | 11,055 | 74,545 |
| Brazil | 419 | 2,242 | 110 | 715 | 17 | 92 | 42 | 258 | 588 | 3,307 |
| Canada | 518 | 3,365 | 607 | 3,696 | 847 | 5,446 | 43,903 | 275,189 | 45,875 | 287,696 |
| Chile | 155 | 223 | 464 | 2,842 | 4,356 | 28,554 | 388 | 2,411 | 5,363 | 34,029 |
| Dominican Republic | -- | -- | -- | -- | 1,521 | 9,395 | 110 | 673 | 1,631 | 10,068 |
| Germany, Federal Republic of | -- | -- | 2 | 18 | 375 | 2,561 | 160 | 1,009 | 537 | 3,582 |
| Mexico | 1,157 | 7,424 | 37 | 302 | 539 | 3,055 | 39,874 | 240,281 | 41,608 | 251,062 |
| Netherlands | -- | -- | 26 | 172 | -- | -- | 1,823 | 11,174 | 1,849 | 11,345 |
| Peru | 8 | 50 | 424 | 2,520 | 384 | 2,494 | 11,252 | 71,164 | 12,068 | 76,228 |
| Switzerland | -- | -- | -- | -- | 109 | 847 | 10,157 | 64,352 | 10,267 | 65,199 |
| United Kingdom | 602 | 3,114 | 9 | 62 | 53 | 365 | 18,990 | 118,685 | 19,654 | 122,175 |
| Other | 637 | 3,563 | 90 | 525 | 158 | 930 | 1,221 | 7,689 | 2,106 | 12,709 |
| Total[1] | 3,533 | 20,180 | 1,771 | 10,854 | 9,900 | 65,364 | 137,398 | 855,550 | 152,601 | 951,947 |

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## Table 14.—Silver: World mine production, by country[1]

(Thousand troy ounces)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria[e] | 110 | 110 | 120 | 120 | 120 |
| Argentina | 2,518 | 2,684 | 2,500 | 1,662 | 1,600 |
| Australia | 23,906 | 29,156 | 33,208 | 31,183 | 35,000 |
| Bolivia | 6,394 | 5,472 | 6,025 | 4,560 | 4,000 |
| Brazil[3] | 765 | 760 | 486 | 829 | 850 |
| Bulgaria[e] | 930 | 930 | 930 | 930 | 930 |
| Burma | 450 | 526 | 558 | 455 | [4]568 |
| Canada | 36,298 | 42,246 | 35,559 | 42,655 | [4]38,889 |
| Chile | 11,610 | 12,288 | 15,055 | 15,766 | [4]16,633 |
| China[e] | 2,500 | 2,500 | 2,500 | 2,500 | 3,000 |
| Colombia[5] | 143 | 136 | 99 | 130 | 200 |
| Costa Rica[e] | 2 | 2 | 2 | 2 | 2 |
| Czechoslovakia[e] | 1,125 | 1,061 | 964 | 1,029 | 1,000 |
| Dominican Republic | 2,034 | [r]2,198 | 1,329 | 1,207 | [4]1,560 |
| Ecuador | 32 | 10 | 3 | 2 | 2 |
| El Salvador | 137 | 86 | 22 | 22 | 20 |
| Fiji | 8 | 19 | 13 | 15 | [4]15 |
| Finland | [r]1,215 | [r]1,188 | 980 | 1,123 | 1,100 |
| France | [r]1,707 | [r]983 | 696 | 770 | 700 |
| German Democratic Republic | 1,450 | 1,450 | 1,380 | 1,290 | 1,400 |
| Germany, Federal Republic of | 1,126 | 1,279 | 1,167 | 1,225 | 1,225 |
| Ghana[e] | 17 | [4]17 | 14 | 14 | 14 |
| Greece | 1,945 | 1,582 | 1,797 | [e]1,800 | 1,700 |
| Greenland[e] | 700 | [r]700 | [r]600 | [r]500 | 500 |
| Guatemala[e] | 8 | [r]3 | (6) | (6) | -- |
| Honduras | 1,823 | 2,100 | 2,587 | [e]2,650 | [4]2,678 |
| India[5] | 555 | 463 | 469 | 862 | [4]778 |
| Indonesia | 830 | 1,134 | 1,135 | 1,121 | 1,170 |
| Ireland | 596 | 352 | 309 | 279 | 250 |
| Italy[5 7] | 1,768 | 1,791 | 2,361 | 1,554 | [4]2,301 |
| Japan | 9,010 | 9,843 | 9,877 | 10,403 | [4]10,899 |
| Korea, North[e] | 1,600 | 1,600 | 1,600 | 1,600 | 1,600 |
| Korea, Republic of | 3,061 | 3,237 | 3,366 | 3,759 | [4]3,990 |
| Malaysia (Sabah) | 465 | 502 | 481 | 470 | 500 |
| Mexico | 52,916 | 59,175 | 63,607 | 75,340 | 69,000 |
| Morocco[e] | 2,120 | 2,640 | 2,850 | [r]2,410 | [4]2,733 |
| Namibia | 3,456 | 2,812 | 3,535 | 3,255 | [4]3,400 |
| New Zealand | -- | -- | (8) | (6) | -- |
| Nicaragua | 140 | 76 | 63 | [e]50 | [4]30 |
| Papua New Guinea | 1,363 | 1,387 | 1,524 | 1,427 | 1,483 |
| Peru | 46,940 | 53,479 | 55,878 | 56,523 | [4]60,395 |
| Philippines | 2,024 | 1,984 | 1,823 | 1,574 | [4]1,743 |
| Poland | 20,576 | 21,123 | 21,798 | 23,920 | 24,000 |
| Portugal | 39 | 24 | 32 | 29 | 30 |
| Romania[e] | 850 | 850 | 820 | 810 | 810 |
| Solomon Islands | (8) | (8) | (8) | -- | -- |
| South Africa, Republic of | 7,568 | 6,943 | 6,513 | 6,997 | [4]6,721 |
| Spain | 5,347 | 3,787 | 1,496 | 4,999 | 5,000 |
| Sweden | 5,170 | 5,395 | 5,491 | 5,793 | [4]6,102 |
| Taiwan | 215 | 504 | 345 | 364 | [4]366 |
| Tunisia | 84 | 115 | 90 | [r] [e]85 | [4]26 |
| Turkey[e] | 200 | 220 | 220 | 220 | 220 |
| U.S.S.R.[e 5] | 46,500 | 46,900 | 47,200 | 47,400 | 47,900 |
| United States | 40,683 | 40,248 | 43,431 | 44,592 | [4]39,357 |
| Yugoslavia[5] | 4,437 | 3,343 | 3,987 | 4,051 | [4]5,015 |
| Zaire | 2,580 | 1,751 | 1,288 | 1,225 | 1,200 |
| Zambia | 714 | 887 | 933 | 795 | 648 |
| Zimbabwe | 857 | 918 | 938 | 893 | 900 |
| **Total** | **[r]361,617** | **[r]382,969** | **392,054** | **415,239** | **412,273** |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Recoverable content of ores and concentrates produced unless otherwise specified. Table includes data available through July 1, 1986.

[2] In addition to the countries listed, Austria and Thailand may produce silver, but information is inadequate to make reliable estimates of output levels.

[3] Of total production, the following quantities, in thousand troy ounces, are identified as placer silver (the balance being silver content of other ores and concentrates): 1981—144; 1982—123; 1983—247; 1984—250 (estimated); and 1985—250 (estimated).

[4] Reported figure.

[5] Smelter and/or refinery production.

[6] Revised to zero.

[7] Includes production from imported ores.

[8] Less than 1/2 unit.

# Slag—Iron and Steel

### By Donald P. Mickelsen[1]

Domestic production of iron and steel slag decreased slightly during 1985. A significant decrease in sales and use of iron slag was partially offset by a strong increase in sales and use of steel slag. Air-cooled iron-blast-furnace slag continued to comprise the largest portion of total blast furnace slag sold or used.

The construction industry was the major user of iron and steel slag products. Air-cooled iron-blast-furnace slag was used mainly for road base, concrete aggregate, asphaltic concrete aggregate, fill, and railroad ballast. The use of air-cooled slag as a road base dropped considerably below that of 1984. Growth areas for iron slag include replacement for cement in concrete construction, use as a concrete aggregate, and as an aggregate in bituminous mixtures. Steel slag was typically used as road base and fill. The average unit value of blast furnace slag increased 13%, and steel slag decreased 11% in unit value from that of 1984.

**Domestic Data Coverage.**—Sales, use, and transportation data for iron and steel slag are developed by the Bureau of Mines from a voluntary annual survey of U.S. processors. Of the 93 operations canvassed, all responded, representing 100% of the total sales or use data shown in table 1. Of the 93 respondents, 87 shipped processed slag, 4 reported their operations as idle, and 2 reported operations as permanently closed.

## DOMESTIC PRODUCTION

Domestic iron and steel slag production, which is not reported to the Bureau of Mines, apparently decreased owing to a slight decline in U.S. iron and steel production. Sales and use of iron and steel slag, when combined, decreased only slightly from that of 1984. Blast furnace slag consumption, however, decreased significantly but was offset by strong increases in the sales and use of steel slag. Sales of all kinds of iron and steel slag were still above the levels of 1982 and 1983, reflecting continued increases in the construction industry which uses most of the slag produced by iron and steel plants. According to the U.S. Department of Commerce, private nonresidential, public, and highway and bridge construction increased 10%, 9%, and 12%, respectively, in 1985.[2] In general, most blast furnace slag processors reported decreases in sales, in some cases owing to a lack of availability of iron slag to process. Most steel slag processors, on the other hand, either reported increases in sales or their sales remained relatively stable. Steel slag sales data also increased because of the addition of 17 operations to the survey.

Blast furnace slag sold or used decreased 10% in quantity yet increased slightly in value compared with that of 1984, totaling 15.1 million short tons valued at $86.9 million. Sixty-six percent of this, in decreasing order, was marketed in Pennsylvania, Ohio, Indiana, and Michigan. Of the blast furnace slag sold or used, 89% was air cooled. During 1985, 38 plants processed iron slag, 1 plant was inactive, and 1 plant closed. Steel slag sold or used totaled 6.0 million tons valued at $17.5 million, up 13% in quantity and only slightly in value com-

## Table 1.—Iron and steel slags sold or used[1] in the United States

(Thousand short tons and thousand dollars)

| Year | Iron-blast-furnace slag | | | | | | | | Steel slag | | Total slag[2] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Air-cooled | | Granulated | | Expanded | | Total iron slag[2] | | | | | |
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| 1981 | 14,461 | 60,164 | 456 | 1,823 | 800 | 4,953 | 15,717 | 66,941 | 5,770 | 17,494 | 21,487 | 84,435 |
| 1982 | 13,617 | 56,816 | 597 | 3,237 | 539 | 4,800 | 14,752 | 64,854 | 4,764 | 14,641 | 19,516 | 79,495 |
| 1983 | 12,380 | 50,999 | ([3]) | ([3]) | 1,175 | 13,736 | 13,554 | 64,735 | 4,832 | 14,546 | 18,386 | 79,280 |
| 1984 | 15,325 | 66,289 | ([3]) | ([3]) | 1,452 | 19,142 | 16,776 | 85,432 | 5,287 | 17,327 | 22,063 | 102,758 |
| 1985 | 13,363 | 62,588 | ([3]) | ([3]) | 1,742 | 24,290 | 15,106 | 86,878 | 5,972 | 17,472 | 21,078 | 104,351 |

[1] Value based on selling price at plant.

[2] Data may not add to totals shown because of independent rounding.

[3] Included with "Expanded" to avoid disclosing company proprietary data.

pared with that of 1984. Sixty plants processed steel slag including 17 operations added to the 1985 survey. Of all iron and steel slag products shipped, 86% traveled by truck with an average marketing range of 30 miles; 8% traveled by waterway with an average marketing range of 394 miles; and 5% traveled by rail with an average marketing range of 153 miles. The remaining 1% was used at the plantsite.

Blue Circle Industries PLC, the largest cement manufacturer in the United Kingdom, purchased the Atlantic Cement Co., a U.S. subsidiary of Newmont Mining Corp., in May. Atlantic's slag cement plant in Sparrows Point, MD, with a capacity of 800,000 tons per year was included in the purchase.[3]

The National Slag Association conducted a survey of physical and chemical characteristics of blast furnace and steel furnace slags produced at U.S. operations by association members. Average chemical analysis of 18 blast furnace slag producers surveyed was as follows: silica ($SiO_2$), 36%; alumina ($Al_2O_3$), 10%; lime (CaO), 39%; magnesia (MgO), 12%; ferric oxide ($Fe_2O_3$), 0.5%; manganese oxide (MnO), 0.44%; and sulfur (S), 1.4%. Average blast furnace slag unit weight was 78 pounds per cubic foot, and absorption was 4.3%. Average analysis of slag from 17 electric arc furnaces (EAF) was as follows: $SiO_2$, 16.9%; $Al_2O_3$, 8.1%; CaO, 41.2%; MgO, 10.2%; MnO, 3.6%; S, 0.23%; ferrous oxide (FeO), 18.1%; iron (Fe), 13.6%; phosphorus pentoxide ($P_2O_5$), 0.63%; and phosphorus (P), 0.43%. Average analysis of slag from 12 basic oxygen furnaces (BOF) was as follows: $SiO_2$, 14.1%; $Al_2O_3$, 1.9%; CaO, 44.4%; MgO, 7.4%; MnO, 5.7%; S, 0.17%; FeO, 22.4%; Fe, 20.7%; $P_2O_5$, 0.75%; and P, 0.28%. Iron analyses shown are averages for iron data reported separately by some producers. The average unit weight and absorption for EAF slags were 106 pounds per cubic foot and 2.5%, and for BOF slags, 126 pounds per cubic foot and 2.4%, respectively.[4]

## CONSUMPTION AND USES

Iron and steel slags, byproducts of ironmaking and steelmaking, were utilized mainly by the construction industry as substitutes for natural aggregates and other construction materials. Historically, iron and steel slags have been used as replacement materials because of economic benefits, better characteristics for some applications, and shortages of natural aggregates in some areas.

Essentially all iron-blast-furnace slag produced is eventually utilized. Of the air-cooled iron-blast-furnace slag sold or used in 1985, 44% was used as road base, 12% as concrete aggregate, 11% as asphaltic concrete aggregate, 10% as fill, and 8% as railroad ballast. The remaining 15% was used for producing mineral wool and in concrete products, roofing, sewage treatment, soil conditioning, glass manufacture, ice control, and other miscellaneous uses. Usage as a road base, while by far the largest end use for air-cooled iron-blast-furnace slag, dropped significantly in 1985, decreasing 27% from that of 1984. Expanded blast furnace slag was mainly used as lightweight concrete aggregate. Concrete products and all other end uses for expanded slag and for granulated blast furnace slag are combined under "Other" to avoid disclosing company proprietary data. Currently, growth areas for iron slag include replacement for cement in concrete construction, use as an aggregate in bituminous mixtures, and use as an aggregate in concrete. As a replacement for cement, ground granulated blast furnace slag offers a savings in natural resources and in energy required to manufacture cement clinker.

Approximately 3.0 million tons of steel slag was recycled to blast furnaces in 1985. The bulk of steel slag produced, however, was used in aggregate applications. Steel slag processed and sold primarily as road base comprised 52%; as fill, 24%; as asphaltic concrete aggregate, 7%; and as railroad ballast, 6%. The remaining 11% was used for ice control and miscellaneous uses. The major growth areas for iron and steel slag usage were as fill and road base.

## PRICES

The average unit price, f.o.b. plant, for all iron-blast-furnace slag sold increased 13% over that of 1984 to $5.75 per ton. Air-cooled slag increased 8% to $4.68 per ton, and expanded slag decreased slightly to $11.00 per ton. Price information for granulated slag was withheld to avoid disclosing company proprietary data. Steel slag unit value was $2.93 per ton, down 11% from that of 1984. Higher prices in some use categories indicate that additional processing was required to meet some users' specifications.

## FOREIGN TRADE

U.S. export and import information for iron and steel slag cannot be determined because slag is classified in nonseparable combined categories. U.S. exports of slag are classified under the schedule heading "Mineral Substances and Articles of Mineral Substances Not Specifically Provided For" and "Waste and Scrap Not Specifically Provided For," while U.S. imports of slag are classified as either "Metal Bearing Ores and Metal Bearing Materials" or "Waste and Scrap Not Specifically Provided For." Blast furnace slag is exported to and imported from Canada periodically.

Basic slag, a byproduct of basic steelmaking processes, is both exported and imported by the United States for use as an artificial fertilizer because of its high lime and phosphorus content. Statistics developed by the U.S. Department of Commerce, Bureau of the Census, indicate that in 1985, 12,000 tons of basic slag valued at $170,220 was imported from Canada, and 418 tons valued at $26,000 was exported to Canada.

## WORLD REVIEW

Estimated world production of iron-blast-furnace slag and steel slag was 126 million and 57 million tons, respectively. Reported production of iron and steel slag by country is incomplete owing to late reporting, insufficiency of data, and lack of reporting by some countries where slag is thought of as a waste product rather than a resource.

**Canada.**—Iron and steel slag in Canada is considered a waste product that creates disposal problems. A recent venture, planned by the Reiss Lime Co. of Canada Ltd., involves the use of slag cement for backfill at the Sudbury and Elliot Lake uranium mines, Ontario. The project entails the production of water granulated blast furnace slag from The Algoma Steel Corp. Ltd.'s Sault Ste. Marie plant to be ground to cement specifications at Reiss' Spragge operation. Slag cement was chosen over regular cement owing to considerable cost savings.[5] The project is expected to cost $9.5 million and provide employment for laid off miners.[6]

**European Economic Community.**—Indicated levels of slag production were essentially unchanged in Europe, since iron and steel production increased only slightly compared with that of 1984. The most current data published by the statistical office of the European Economic Community (EEC) show that a total of 20,570,207 tons of iron-blast-furnace slag was produced in the EEC in 1984.[7]

**Japan.**—A world leader in iron and steel production, Japan produced and utilized an estimated 26 million tons of iron slag and 14 million tons of steel slag, virtually the same as that in 1984. Approximately 40% of the blast furnace slag consumed was used in cement manufacture, and 35% was used for roadbed aggregate and railroad ballast. The remainder was used for concrete aggregate, fertilizer, soil conditioner, and other uses.[8] Most of the steel slag produced was used in road construction.

## TECHNOLOGY

In 1984, the Oakland County Road Commission in Michigan used blast furnace slag in two unique roadbed designs intended to correct soft, unstable subsoil conditions for highway expansion. The first design utilized Tensar high-strength polymer reinforcing geogrids between layers of lightweight blast furnace slag. The Orchard Lake Road had a 600-foot stretch of historically unstable roadbed to be expanded, having as much as 25 feet of soft, saturated subsoils beneath. Multiple layers of compacted lightweight blast furnace slag alternated with layers of overlapping Tensar geogrid were used to prevent consolidation of the roadway, to distribute horizontal stresses, and to tie the subbase together. After 16 months of use, with average daily trips of 22,400, the highway reportedly showed no signs of stress.

The second design, used to widen Opdyke Road onto soft compressive subsoil, involved encapsulating an 18-inch-thick by 23-foot-wide compacted subbase of 6A gradation (3/8 to 1-1/4 inches) blast furnace slag with a Mirafi woven stabilization fabric. The result was a 23-foot-wide mat foundation used to stabilize the subgrade and on top of which the roadway was constructed. The project was completed in 1981 and after about 4 years of service, with average daily trips of 18,000, the highway reportedly showed no visible signs of settlement.[9]

The Aerofall mill, a dry, air-swept grinding mill, was described in a recent paper. The Aerofall mill system is designed to process course feed material from a primary crusher; to separate, clean and discharge metallics; and to reduce nonmetallics to a dry ground product in a single stage. The mill can be used for the grinding of various metallurgical slags, including iron and steel slags. It is currently being used to process iron and steel slag in Japan and iron-titanium slag in the Republic of South Africa as well as petroleum coke and various metallurgical drosses in the United States.[10]

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[1] Mineral data specialist, Division of Ferrous Metals.

[2] U.S. Department of Commerce. Construction Review. V. 31, No. 6, Nov.-Dec. 1985, pp. 2, 8-14.

[3] Industrial Minerals (London). World of Minerals: USA-Blue Circle to Acquire Atlantic Cement. No. 212, May 1985, p. 18.

[4] National Slag Association. 1985 Survey of Physical and Chemical Characteristics of Blast-Furnace and Steel-Furnace Slags. MF185-3, 1985, 5 pp.

[5] Mining Journal. V. 305, No. 7826, Aug. 16, 1985, p. 118.

[6] Where necessary, values have been converted from Canadian dollars (CAN$) to U.S. dollars at the rate of CAN$1.3188 = US$1.00, the average exchange rate for 1985.

[7] Statistical Office of the European Economic Community. 1985 Iron and Steel Yearbook, p. 74.

[8] National Slag Association. Bulletin: Utilization of Blast-Furnace Slag in Japan. No. 4-85, Mar. 29, 1985, p. 1.

[9] ———. Slag Used in Unique Designs For Highway Base Over Very Soft Sub-soil. MF185-7, 1985, 3 pp.

[10] Heath, R. A. The Aerofall Mill Applied to Industrial Materials. Paper on Recycle and Secondary Recovery of Metals, ed. by P. R. Taylor, H. Y. Sohn, and N. Jarrett (Proc. at Symp. Metall. Soc. AIME, Ft. Lauderdale, FL, Dec. 1-4, 1985). Metall. Soc. AIME, Warrendale, PA, 1985, pp. 625-635.

### Table 2.—Iron-blast-furnace slags sold or used[1] in the United States, by region and State

(Thousand short tons and thousand dollars)

| Region and State | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Air-cooled, screened and unscreened | | Total, all types | | Air-cooled, screened and unscreened | | Total, all types | |
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| North Central: | | | | | | | | |
| Illinois, Indiana, Michigan | 4,878 | 16,780 | W | W | 4,424 | 17,488 | W | W |
| Ohio | 2,348 | 12,225 | W | W | 2,460 | 13,818 | W | W |
| Total | 7,226 | 29,005 | 7,751 | 32,387 | 6,884 | 31,306 | 7,483 | 35,708 |
| Middle Atlantic: | | | | | | | | |
| Pennsylvania | 3,773 | 20,485 | W | W | 2,488 | 13,298 | W | W |
| Maryland, New York, West Virginia | 957 | 4,374 | W | W | 1,066 | 4,603 | W | W |
| Total | 4,730 | 24,859 | 5,656 | 40,619 | 3,554 | 17,901 | 4,696 | 37,789 |
| West: Colorado, Texas, Utah | 2,225 | 6,071 | 2,225 | 6,071 | 1,508 | 5,754 | 1,508 | 5,754 |
| South: Alabama and Kentucky | 858 | 5,329 | 858 | 5,329 | 875 | 5,719 | 875 | 5,719 |
| Pacific: California | 288 | 1,026 | 288 | 1,026 | 543 | 1,908 | 543 | 1,908 |
| Grand total[2] | 15,325 | 66,289 | 16,776 | 85,432 | 13,363 | 62,588 | 15,106 | 86,878 |

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Value based on selling price at plant.

[2] Data may not add to totals shown because of independent rounding.

## Table 3.—Locations and processing methods of iron slag and sources of steel slag[1] in 1985

| State, city, and company | Processing method of iron slag | | | Steel slag | Sources of steel slag | | |
|---|---|---|---|---|---|---|---|
| | Air-cooled | Expanded | Granulated | | Open hearth | Basic oxygen process | Electric |
| **Alabama:** | | | | | | | |
| **Alabama City:** | | | | | | | |
| **Vulcan Materials Co** | 1 | -- | -- | 1 | -- | 1 | -- |
| **Fairfield:** | | | | | | | |
| **Vulcan Materials Co** | 1 | -- | -- | 1 | -- | 1 | -- |
| **Total** | 2 | -- | -- | 2 | -- | 2 | -- |
| **California: Fontana:** | | | | | | | |
| **Heckett Co** | 1 | -- | -- | -- | -- | -- | -- |
| **Colorado: Pueblo:** | | | | | | | |
| **Fountain Sand and Gravel Co** | 1 | -- | -- | -- | -- | -- | -- |
| **Delaware: Claymont:** | | | | | | | |
| **International Mill Service Co** | -- | -- | -- | 1 | -- | 1 | -- |
| **Florida: Tampa:** | | | | | | | |
| **International Mill Service Co** | -- | -- | -- | 1 | -- | -- | 1 |
| **Georgia:** | | | | | | | |
| **Atlanta:** | | | | | | | |
| **International Mill Service Co** | -- | -- | -- | 1 | -- | -- | 1 |
| **Cartersville:** | | | | | | | |
| **International Mill Service Co** | -- | -- | -- | 1 | -- | -- | 1 |
| **Total** | -- | -- | -- | 2 | -- | -- | 2 |
| **Illinois:** | | | | | | | |
| **Alton:** | | | | | | | |
| **International Mill Service Co** | -- | -- | -- | 1 | -- | -- | 1 |
| **Chicago:** | | | | | | | |
| **Heckett Co** | -- | -- | -- | 1 | -- | 1 | 1 |
| **Heckett Co** | 1 | -- | -- | -- | -- | -- | -- |
| **International Mill Service Co** | -- | -- | -- | 1 | -- | 1 | -- |
| **Granite City:** | | | | | | | |
| **International Mill Service Co** | -- | -- | -- | 1 | -- | 1 | -- |
| **St. Louis Slag Products Co. Inc** | 1 | -- | -- | -- | -- | -- | -- |
| **Peoria:** | | | | | | | |
| **International Mill Service Co** | -- | -- | -- | 1 | -- | -- | 1 |
| **Total** | 2 | -- | -- | 5 | -- | 3 | 3 |
| **Indiana:** | | | | | | | |
| **Burns Harbor:** | | | | | | | |
| **The Levy Co. Inc** | 1 | 1 | -- | 1 | -- | 1 | -- |
| **East Chicago:** | | | | | | | |
| **Heckett Co** | -- | -- | -- | 1 | -- | 1 | -- |
| **Vulcan Materials Co** | 1 | -- | -- | -- | -- | -- | -- |
| **Gary:** | | | | | | | |
| **International Mill Service Co** | -- | -- | -- | 1 | -- | 1 | 1 |
| **Kokomo:** | | | | | | | |
| **International Mill Service Co** | -- | -- | -- | 1 | -- | -- | 1 |
| **Total** | 2 | 1 | -- | 4 | -- | 3 | 2 |
| **Iowa: Keokuk:** | | | | | | | |
| **International Mill Service Co** | -- | -- | -- | 1 | -- | -- | 1 |
| **Kentucky:** | | | | | | | |
| **Ashland:** | | | | | | | |
| **Heckett Co** | 1 | -- | -- | -- | -- | -- | -- |
| **Owensboro:** | | | | | | | |
| **Heckett Co** | -- | -- | -- | 1 | -- | -- | 1 |
| **Total** | 1 | -- | -- | 1 | -- | -- | 1 |
| **Louisiana: LaPlace:** | | | | | | | |
| **International Mill Service Co** | -- | -- | -- | 1 | -- | -- | 1 |

**See footnote at end of table.**

## Table 3.—Locations and processing methods of iron slag and sources of steel slag[1] in 1985 —Continued

| State, city, and company | Processing method of iron slag | | | Steel slag | Sources of steel slag | | |
|---|---|---|---|---|---|---|---|
| | Air-cooled | Expanded | Granulated | | Open hearth | Basic oxygen process | Electric |
| Maryland: | | | | | | | |
| Baltimore: | | | | | | | |
| Maryland Slag Co | 1 | -- | -- | -- | -- | -- | -- |
| Sparrows Point: | | | | | | | |
| Blue Circle Atlantic | -- | -- | 1 | -- | -- | -- | -- |
| C. J. Langenfelder & Sons Inc | -- | -- | -- | 1 | 1 | 1 | -- |
| Total | 1 | -- | 1 | 1 | 1 | 1 | -- |
| Michigan: Detroit: | | | | | | | |
| Edward C. Levy Co | 1 | 1 | -- | 1 | -- | 1 | 1 |
| Minnesota: Newport: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| Missouri: Kansas City: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| New Jersey: | | | | | | | |
| Perth Amboy: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| Riverton: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| Total | -- | -- | -- | 2 | -- | -- | 2 |
| New York: Buffalo: | | | | | | | |
| Buffalo Crushed Stone Corp | 1 | -- | -- | -- | -- | -- | -- |
| North Carolina: Charlotte: | | | | | | | |
| Heckett Co | -- | -- | -- | 1 | -- | -- | 1 |
| Ohio: | | | | | | | |
| Canton: | | | | | | | |
| Heckett Co | -- | -- | -- | 1 | -- | -- | 1 |
| Cleveland: | | | | | | | |
| Standard Slag Co | 1 | -- | -- | -- | -- | -- | -- |
| Standard Slag Co | 1 | -- | -- | -- | -- | -- | -- |
| Stein Inc | -- | -- | -- | 1 | -- | 1 | 1 |
| Hamilton: | | | | | | | |
| American Materials Corp | 1 | -- | -- | -- | -- | -- | -- |
| Lorain: | | | | | | | |
| Fritz Enterprises Inc | 1 | -- | -- | -- | -- | -- | -- |
| Stein Inc | -- | -- | -- | 1 | -- | 1 | -- |
| Lordstown: | | | | | | | |
| Standard Slag Co | -- | -- | 1 | -- | -- | -- | -- |
| Mansfield: | | | | | | | |
| Heckett Co | -- | -- | -- | 1 | -- | -- | 1 |
| Marion: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| Middletown: | | | | | | | |
| American Materials Corp | 1 | -- | -- | -- | -- | -- | -- |
| International Mill Service Co | -- | -- | -- | 1 | -- | 1 | -- |
| Mingo Junction: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | 1 | -- |
| Standard Slag Co | 1 | -- | -- | -- | -- | -- | -- |
| Warren: | | | | | | | |
| Heckett Co | -- | -- | -- | 1 | -- | 1 | 1 |
| Standard Slag Co | 1 | -- | -- | -- | -- | -- | -- |
| Total | 7 | -- | 1 | 8 | -- | 5 | 5 |
| Oklahoma: Sand Springs: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |

See footnote at end of table.

### Table 3.—Locations and processing methods of iron slag and sources of steel slag[1] in 1985 —Continued

| State, city, and company | Processing method of iron slag | | | Steel slag | Sources of steel slag | | |
|---|---|---|---|---|---|---|---|
| | Air-cooled | Expanded | Granulated | | Open hearth | Basic oxygen process | Electric |
| Pennsylvania: | | | | | | | |
| Bala-Cynwyd: | | | | | | | |
| Warner Co | 1 | 1 | -- | -- | -- | -- | -- |
| Beaver Falls: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| Belle Vernon: | | | | | | | |
| Duquesne Slag Products Co | 1 | -- | -- | -- | -- | -- | -- |
| Bethlehem: | | | | | | | |
| Bethlehem Mines Corp | 1 | -- | -- | -- | -- | -- | -- |
| Sheridan Slag Corp | -- | 1 | -- | -- | -- | -- | -- |
| Burgettstown: | | | | | | | |
| Duquesne Slag Products Co | -- | -- | 1 | -- | -- | -- | -- |
| Butler: | | | | | | | |
| Heckett Co | -- | -- | -- | 1 | -- | -- | 1 |
| Coatesville: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| Johnstown: | | | | | | | |
| Heckett Co | -- | -- | -- | 1 | -- | -- | 1 |
| Lebanon: | | | | | | | |
| Sheridan Slag Corp | 1 | -- | -- | -- | -- | -- | -- |
| Midland: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| Monessen: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | 1 | -- |
| Morrisville: | | | | | | | |
| Heckett Co | -- | -- | -- | 1 | 1 | -- | -- |
| Patton: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | 1 | -- |
| Penn Hills: | | | | | | | |
| Gascola Slag Co | -- | -- | -- | 1 | 1 | -- | -- |
| Phoenixville: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| Riddlesburg: | | | | | | | |
| New Enterprise Stone & Lime Co. Inc | 1 | -- | -- | -- | -- | -- | -- |
| Steelton: | | | | | | | |
| Hempt Bros. Inc | -- | -- | -- | 1 | -- | -- | 1 |
| West Aliquippa: | | | | | | | |
| Duquesne Slag Products Co | 1 | -- | -- | 1 | -- | 1 | -- |
| West Mifflin: | | | | | | | |
| Duquesne Slag Products Co | 1 | -- | -- | -- | -- | -- | -- |
| Duquesne Slag Products Co | 1 | -- | -- | 1 | -- | 1 | -- |
| Wheatland: | | | | | | | |
| Dunbar Slag Co. Inc | 1 | -- | -- | 1 | 1 | 1 | -- |
| Total | 9 | 2 | 1 | 14 | 3 | 5 | 7 |
| South Carolina: Georgetown: | | | | | | | |
| Heckett Co | -- | -- | -- | 1 | -- | -- | 1 |
| Texas: | | | | | | | |
| Baytown: | | | | | | | |
| Heckett Co | -- | -- | -- | 1 | -- | -- | 1 |
| Beaumont: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| El Paso: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| Lone Star: | | | | | | | |
| Gifford-Hill Co. Inc | 1 | -- | -- | -- | -- | -- | -- |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| Longview: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| Midlothian: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |

See footnote at end of table.

### Table 3.—Locations and processing methods of iron slag and sources of steel slag[1] in 1985 —Continued

| State, city, and company | Processing method of iron slag | | | Steel slag | Sources of steel slag | | |
|---|---|---|---|---|---|---|---|
| | Air-cooled | Ex-panded | Granu-lated | | Open hearth | Basic oxygen process | Elec-tric |
| **Texas —Continued** | | | | | | | |
| Sequin: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| Total | 1 | -- | -- | 7 | -- | -- | 7 |
| **Utah:** | | | | | | | |
| Plymouth: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | -- | 1 |
| Provo: | | | | | | | |
| Heckett Co | 1 | -- | -- | 1 | 1 | -- | -- |
| Total | 1 | -- | -- | 2 | 1 | -- | 1 |
| **Washington: Seattle:** | | | | | | | |
| Heckett Co | -- | -- | -- | 1 | -- | -- | 1 |
| **West Virginia:** | | | | | | | |
| Weirton: | | | | | | | |
| International Mill Service Co | -- | -- | -- | 1 | -- | 1 | -- |
| Standard Slag Co | 1 | -- | -- | -- | -- | -- | -- |
| Total | 1 | -- | -- | 1 | -- | 1 | -- |
| Grand total | 31 | 4 | 3 | 60 | 5 | 22 | 40 |

[1] Number indicates the existence of an active plant shown by processing method or furnace source; previous years showed the number of active processing lines for some plants.

### Table 4.—Shipments of iron and steel slag in the United States in 1985, by method of transportation

| Method of transportation | Quantity (thousand short tons) |
|---|---|
| Truck | 18,158 |
| Waterway | 1,717 |
| Rail | 973 |
| Not transported (used at plantsite) | 230 |
| Total | 21,078 |

### Table 5.—Air-cooled iron-blast-furnace slag sold or used[1] in the United States, by use

(Thousand short tons and thousand dollars)

| Use | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Asphaltic concrete aggregate | 1,271 | 6,601 | 1,503 | 7,149 |
| Concrete aggregate | 1,396 | 6,350 | 1,613 | 8,740 |
| Concrete products | 539 | 2,588 | 495 | 2,226 |
| Fill | 1,515 | 4,671 | 1,299 | 4,366 |
| Glass manufacture | 165 | 2,022 | 110 | W |
| Mineral wool | 607 | 3,913 | 617 | 4,081 |
| Railroad ballast | 1,136 | 4,522 | 1,024 | 4,656 |
| Road base | 8,020 | 32,632 | 5,831 | 24,772 |
| Roofing, built-up and shingles | 283 | 1,670 | 156 | 1,114 |
| Sewage treatment | 121 | 461 | 445 | 2,314 |
| Soil conditioning | 49 | 158 | 48 | 173 |
| Other[2] | 224 | 701 | 221 | [3]3,000 |
| Total[4] | 15,325 | 66,289 | 13,363 | 62,588 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Value based on selling price at plant.

[2] Includes ice control, miscellaneous, and value indicated by symbol W.

[3] Includes glass manufacture.

[4] Data may not add to totals shown because of independent rounding.

## Table 6.—Granulated and expanded iron-blast-furnace slags sold or used[1] in the United States, by use

(Thousand short tons and thousand dollars)

| Uses | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Granulated | | Expanded | | Granulated | | Expanded | |
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| Cement manufacture | (2) | (2) | W | W | (2) | (2) | W | W |
| Concrete products | -- | -- | W | W | -- | -- | -- | -- |
| Fill | -- | -- | -- | -- | (2) | (2) | W | W |
| Lightweight concrete aggregate | -- | -- | 229 | 2,271 | -- | -- | W | W |
| Road base | (2) | (2) | W | W | (2) | (2) | W | W |
| Soil conditioning | (2) | (2) | W | W | (2) | (2) | W | W |
| Other[3] | -- | -- | 1,223 | 16,871 | -- | -- | 1,742 | 24,290 |
| Total | (2) | (2) | 1,452 | 19,142 | (2) | (2) | 1,742 | 24,290 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Value based on selling price at plant.

[2] Included with "Expanded" to avoid disclosing company proprietary data.

[3] Includes miscellaneous and data indicated by symbol W.

## Table 7.—Steel slag sold or used[1] in the United States, by use

(Thousand short tons and thousand dollars)

| Use | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Asphaltic concrete aggregate | 551 | 2,854 | 417 | 1,811 |
| Fill | 1,037 | 3,230 | 1,436 | 4,145 |
| Railroad ballast | W | W | 365 | 1,249 |
| Road base | 2,595 | 7,463 | 3,079 | 9,050 |
| Other[2] | 1,104 | 3,780 | 674 | 1,219 |
| Total[3] | 5,287 | 17,327 | 5,972 | 17,472 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Excludes tonnage returned to furnace for charge material. Value based on selling price at plant.

[2] Includes ice control, soil conditioning, miscellaneous uses, and data indicated by symbol W.

[3] Data may not add to totals shown because of independent rounding.

## Table 8.—Average value at the plant for iron and steel slags sold or used in the United States

(Dollars per short ton)

| Year | Iron-blast-furnace slag | | | | Steel slag | Total slag |
|---|---|---|---|---|---|---|
| | Air-cooled | Granulated | Expanded | Total iron slag | | |
| 1981 | 4.16 | 4.00 | 6.19 | 4.26 | 3.03 | 3.93 |
| 1982 | 4.17 | 5.42 | 8.91 | 4.40 | 3.07 | 4.07 |
| 1983 | 4.12 | W | 9.67 | 4.78 | 3.01 | 4.31 |
| 1984 | 4.33 | W | 11.49 | 5.09 | 3.28 | 4.66 |
| 1985 | 4.68 | W | 11.00 | 5.75 | 2.93 | 4.95 |

W Withheld to avoid disclosing company proprietary data.

Table 9.—Average selling price and range of selling prices at the plant for iron and steel slags in the United States in 1985, by use

(Dollars per short ton)

| Use | Iron-blast-furnace slag | | | | | | Steel slag | |
|---|---|---|---|---|---|---|---|---|
| | Air-cooled | | Granulated | | Expanded | | | |
| | Average | Range | Average | Range | Average | Range | Average | Range |
| Asphaltic concrete aggregate | 4.75 | 2.01- 8.00 | -- | -- | -- | -- | 4.34 | 1.28-8.26 |
| Cement manufacture | -- | -- | W | W | -- | -- | -- | -- |
| Concrete aggregate | 5.41 | 2.76- 7.01 | -- | -- | -- | -- | -- | -- |
| Concrete products | 4.49 | 3.00- 7.01 | -- | -- | -- | -- | -- | -- |
| Fill | 3.85 | 2.00- 5.91 | W | W | -- | -- | 2.88 | .52-6.15 |
| Glass manufacture | W | W | -- | -- | -- | -- | -- | -- |
| Lightweight concrete aggregate | -- | -- | -- | -- | 11.00 | 9.00-12.67 | -- | -- |
| Mineral wool | 6.61 | 2.75-10.54 | -- | -- | -- | -- | -- | -- |
| Railroad ballast | 4.54 | 2.75- 7.60 | -- | -- | -- | -- | 3.41 | .75-9.48 |
| Road base | 4.24 | 2.29- 7.01 | W | W | -- | -- | 2.93 | .70-8.21 |
| Roofing, built-up and shingles | 7.13 | 3.51-10.64 | -- | -- | -- | -- | -- | -- |
| Sewage treatment | 5.20 | 3.51- 7.55 | -- | -- | -- | -- | -- | -- |
| Soil conditioning | 3.58 | 3.00- 5.28 | W | W | -- | -- | W | W |
| Other | 4.06 | 1.73- 5.63 | -- | -- | -- | -- | 1.80 | 1.00-8.18 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

# Sodium Compounds

### By Dennis S. Kostick[1]

The U.S. soda ash industry took advantage of the tight supply of foreign soda ash for the world market by increasing its export sales, which reached a record-high level. Domestic consumption of soda ash decreased for the third consecutive year because of competition from recycled glass, or cullet, and continued erosion of the glass container market by polyethylene terephthalate (PET) bottles. Domestic production of natural and synthetic sodium sulfate decreased to an all-time low because of the closure of two byproduct sodium sulfate plants and the availability of inexpensive substitutive caustic soda and emulsified sulfur.

**Domestic Data Coverage.**—Domestic production data for soda ash and sodium sulfate are developed by the Bureau of Mines from monthly and annual voluntary surveys of U.S. operations. Of the eight soda ash operations and four sodium sulfate operations to which a survey request was sent, all responded, representing 100% of the total production data shown in table 1. Two soda ash producers did not report sales value on these forms; however, their data were estimated and included in table 1.

**Table 1.—Salient sodium compound statistics**

(Thousand short tons and thousand dollars)

| | Soda ash | | Sodium sulfate | |
|---|---|---|---|---|
| | 1984 | 1985 | 1984 | 1985 |
| United States: | | | | |
| Production[1] | 8,511 | 8,597 | 872 | 827 |
| Value[2] | [e]$611,000 | [e]$622,253 | $80,433 | $76,237 |
| Exports | 1,648 | [3]1,771 | 76 | 119 |
| Value | $160,774 | [3]$186,064 | $9,587 | $11,899 |
| Imports for consumption | 17 | 56 | 265 | 194 |
| Value | $2,301 | $8,089 | $21,198 | $14,492 |
| Stocks, Dec. 31: Producers | [4]322 | [4]428 | [5]59 | [5]31 |
| Consumption, apparent | 6,864 | 6,777 | 1,050 | 930 |
| World: Production | [p]31,126 | [e]31,628 | [p]4,697 | [e]4,647 |

[e] Estimated. [p] Preliminary.

[1] Includes natural and synthetic. Total production data for sodium sulfate obtained from the Bureau of the Census.

[2] The value for soda ash includes synthetic soda ash. The value for synthetic sodium sulfate is based upon the average value for natural sodium sulfate.

[3] Export data from the Bureau of the Census were adjusted by the Bureau of Mines pending data reconciliation between the Bureau of the Census and the American Natural Soda Ash Corp.

[4] Includes synthetic soda ash.

[5] Natural only.

**Legislation and Government Programs.**—The U.S. Department of Commerce and several members of the U.S. Congress supported soda ash for inclusion on the President's Trade Strike Force. Trade barriers, such as inhibitive import permits, tariffs, embargoes, and nonenforcement of antimonopoly laws, in several countries have impeded the export efforts of the U.S. soda ash industry. These trade practices served to protect the host countries' synthetic soda ash production facilities. Whereas certain domestic mineral industries had sought and been denied Federal action for relief from low-cost imports, the soda ash industry was seeking Government support for its export efforts. Further discussions on this issue were planned for 1986.[3]

## DOMESTIC PRODUCTION

**Soda Ash.**—The domestic industry operated at 76% of combined nameplate capacity as production of natural and synthetic soda ash increased for the third consecutive year to reach a record high despite a slight decline in the amount of Wyoming soda ash produced. Wyoming trona production by five companies was 11,796,000 million short tons, or 9% less than the record high of 12,906,000 million tons reported in 1980. This decrease was attributed to an increase in the soda ash-trona refining efficiency ratio—more tons of soda ash processed from fewer tons of trona mined—and the decrease in Wyoming soda ash production.

Acquisitions and divestitures by parent corporations affected some of the domestic soda ash companies. Chesebrough-Ponds Inc. acquired Stauffer Chemical Co.; Anaconda Minerals Co. sought a buyer for its share of a sodium carbonate deposit at Searles Lake in California; and Allied Corp. announced plans to close its 700,000-ton-per-year synthetic soda ash plant by March 1986. Allied later merged with Signal Corp. to become Allied-Signal Corp. and transferred its soda ash operations to the Henley Group, a newly formed spinoff company. Allied's announcement prompted Church & Dwight Co. Inc., the Nation's largest sodium bicarbonate manufacturer, to cease production at its 96,000-ton-per-year facility, which used sodium carbonate from Allied as feedstock.

Kerr-McGee Chemical Corp. announced that all soda ash production would be phased out at its Searles Lake Westend facility by 1987. The plant has had a capacity of about 150,000 tons per year. FMC Wyoming Corp. began solution mining commercial quantities of soda ash. Upon reaching full-scale production planned for 1987, the operation was expected to have more than 250,000 tons per year of soda ash capacity, which would replace a comparable amount of underground mining capacity.

**Table 2.—Producers of soda ash and natural sodium sulfate in 1985**

| Product and company | Plant nameplate capacity (thousand short tons) | Plant location | Source of sodium |
|---|---|---|---|
| Soda ash, natural: | | | |
| Allied Chemical Co[1] | 2,200 | Green River, WY. | Underground trona. |
| FMC Wyoming Corp | 2,850 | do | Do. |
| Kerr-McGee Chemical Corp | 1,300 | Argus, CA | Dry lake brine. |
| Do | 150 | Westend, CA | Do. |
| Stauffer Chemical Co. of Wyoming[2] | 1,960 | Green River, WY. | Underground trona. |
| Tenneco Minerals Co | 1,000 | do | Do. |
| T. G. Soda Ash Inc | 1,100 | Granger, WY | Do. |
| Soda ash, synthetic: | | | |
| Allied Chemical Co.[3] | 700 | Syracuse, NY | Ammonia-soda process. |
| Total | 11,260 | | |
| Sodium sulfate: | | | |
| Great Salt Lake Minerals & Chemicals Corp.[4] | 50 | Ogden, UT | Salt lake brine. |
| Kerr-McGee Chemical Corp | 240 | Westend, CA | Dry lake brine. |
| Ozark-Mahoning Co | 70 | Brownfield, TX. | Subterranean brine. |
| Do | 150 | Seagraves, TX | Do. |
| Total | 510 | | |

[1] Allied Corp. merged with Signal Corp. to become Allied-Signal Corp.
[2] Acquired by Chesebrough-Ponds Inc.
[3] Plant was downrated from 900,000 tons per year in Jan. 1983.
[4] Solar ponds were flooded May 5, 1984. No significant production in 1985.

**Sodium Sulfate.**—Allied-Signal permanently closed its sodium bichromate and byproduct sodium sulfate facility at Baltimore, MD, at midyear. Climax Chemical Corp. modified its Grantsville, UT, plant to produce potassium sulfate instead of sodium sulfate. These actions resulted in the loss of about 135,000 tons of sodium sulfate annual capacity.

**Table 3.—Synthetic and natural sodium carbonates produced in the United States**

(Thousand short tons and thousand dollars)

| Year | Synthetic soda ash (ammonia-soda process)[1] | Natural sodium carbonates[2] | | Total quantity |
|---|---|---|---|---|
| | Quantity | Quantity | Value[3] | |
| 1981 | W | W | 787,469 | 8,281 |
| 1982 | W | W | 721,257 | 7,819 |
| 1983 | W | W | $^{e}$685,100 | 8,467 |
| 1984 | W | W | $^{e}$611,000 | 8,511 |
| 1985 | W | W | $^{e}$622,253 | 8,597 |

$^{e}$Estimated. W Withheld to avoid disclosing company proprietary data.

[1] Includes quantities used to manufacture caustic soda, sodium bicarbonate, and finished light and dense soda ash.

[2] Soda ash and trona (sesquicarbonate).

[3] Includes value for synthetic soda ash.

**Table 4.—Synthetic and natural sodium sulfate[1] produced in the United States**

(Thousand short tons and thousand dollars)

| Year | Synthetic and natural[2] (quantity) | | | Natural | |
|---|---|---|---|---|---|
| | Lower purity[3] (99% or less) | High purity | Total[4] | Quantity | Value |
| 1981 | 666 | 445 | 1,111 | 608 | 43,186 |
| 1982 | 463 | 401 | 864 | W | W |
| 1983 | 427 | 427 | 855 | 423 | 39,425 |
| 1984 | $^{r}$428 | $^{r}$444 | 872 | 435 | 40,125 |
| 1985 | 401 | 428 | 827 | 389 | 35,860 |

$^{r}$Revised. W Withheld to avoid disclosing company proprietary data.

[1] All quantities converted to 100% $Na_2SO_4$ basis.

[2] Current Industrial Reports, Inorganic Chemicals, Bureau of the Census.

[3] Includes Glauber's salt.

[4] Data may not add to totals shown because of independent rounding.

## CONSUMPTION AND USES

**Soda Ash.**—Increased use of PET containers by the food and beverage industries continued to inhibit sales of soda ash to the glass container industry. Approximately 1.3 million tons of cullet collected for reuse also reduced soda ash sales. These losses were offset by the strength of the construction and automotive industries, which were major consumers of fiberglass and of flat glass, accounting for 55% and 20% of the total flat glass market, respectively. As automobile manufacturers strive to reduce vehicle weight and thereby gasoline consumption, the quantity of glass per vehicle was forecast to decrease nearly 13% by 1992.[3]

Liquid detergents have become increasingly popular among consumers because of their convenience. In 1985, the market share of liquid home detergents increased 5% over that of 1984 and represented 30% of the home detergent market. Because powdered detergents contain soda ash in their formulations, but liquid detergents do not, the increasing preference for liquid detergents was expected to constrain domestic soda ash demand. The use of soda ash in the manufacture of sodium tripolyphosphate (STPP) for powdered detergents increased 4% in 1985, despite the ban of STPP in one-fourth of the States because of environmental considerations.

**Sodium Sulfate.**—Apparent consumption decreased to an all-time low because of competition from inexpensive and available caustic soda and emulsified sulfur, which were substituted for low-purity sodium sulfate, known as saltcake, in the pulp and paper industry. In addition, the use of sodium sulfate declined in glass container manufacturing and in detergent production. Sodium sulfate had been used as a filler in powdered detergent formulations, but most manufacturers were removing fillers and replacing them with additional builders, such as STPP. Liquid detergents do not contain sodium sulfate in their composition.

**Table 5.—Estimated consumption of soda ash in the United States, by end use**

(Thousand short tons)

| End use | 1984 | 1985 |
|---|---|---|
| Glass: | | |
| Bottle and container | 2,300 | 2,200 |
| Flat | 600 | 700 |
| Fiber | 250 | 275 |
| Other | 250 | 225 |
| Total | 3,400 | 3,400 |
| Chemicals | 1,550 | 1,500 |
| Soaps and detergents | 600 | 600 |
| Pulp and paper | 250 | 350 |
| Water and stackgas | 600 | 600 |
| Other[1] | 464 | 327 |
| Total | 3,464 | 3,377 |
| Grand total | 6,864 | 6,777 |

[1] Includes soda ash used in petroleum and metal refining, leather tanning, enamels, etc.

## STOCKS

**Soda Ash.**—Yearend stocks of dense and light soda ash in plant silos, warehouses, terminals, and on teamtracks amounted to 428,000 tons, or 33% more than 1984 yearend inventories.

**Sodium Sulfate.**—Inventories of natural sodium sulfate decreased 47%, primarily because of reduced domestic industry production capability and weak domestic demand.

## PRICES

**Soda Ash.**—In mid-1985, the soda ash industry reduced the temporary voluntary allowance on soda ash from $11 to $7 per ton. This action effectively raised the f.o.b. price per ton from $79 to $83 in Wyoming and from $109.25 to $113.25 in California. The average annual value of natural soda ash, f.o.b. Green River, WY, and Searles Valley, CA, was estimated to be $67.82 per ton.

**Sodium Sulfate.**—The average annual value of bulk natural product, f.o.b. mine or plant, was $92.19 per ton.

### Table 6.—Sodium compounds yearend prices

| | 1984 | 1985 |
|---|---|---|
| Sodium carbonate (soda ash): | | |
| Light, paper bags, carlots, works per ton | $150.00 | $150.00 |
| Light, bulk, carlots, works do. | 123.00 | 123.00 |
| Dense, paper bags, carlots, works do. | 120.00 | 120.00 |
| Dense, bulk, carlots, works do. | 90.00 | 90.00 |
| Sodium sulfate (100% $Na_2SO_4$): | | |
| Technical detergent, rayon grade, bags, carlots do. | $90.00- 96.00 | $90.00- 96.00 |
| Sodium sulfate, bulk, carlots, works[1] do. | 113.00- 114.00 | 113.00- 114.00 |
| Domestic salt cake, bulk, works[1] do. | 47.00- 53.00 | 47.00- 53.00 |
| National Formulary (N.F. XII), drums per pound | .235 | .235 |

[1] East of Mississippi River.

Source: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 226, No. 27, Dec. 31, 1984, p. 27, and v. 227, No. 27, Dec. 30, 1985, p. 27.

## FOREIGN TRADE

**Soda Ash.**—Exports of 1.639 million tons of soda ash reported by the Bureau of the Census were adjusted to include an additional 132,000 tons, pending data reconciliation between the Bureau of the Census and the American National Soda Ash Corp. Total exports, as adjusted by the Bureau of Mines, were 1.771 million tons. Exports to 43 countries, on a regional basis, were as follows: Asia, 60%; North America, 14%; Latin America, 12%; Africa, 9%; Oceania, 3%; and the Caribbean and Europe, 1% each.

At yearend, the Republic of Korea agreed to lift import controls on 603 products, including soda ash, over the following 3 years. This action offered potential for increasing U.S. exports.

Four companies comprising the Japanese synthetic soda ash industry considered filing dumping charges against U.S. producers. The Japanese claimed that U.S. soda ash consumers paid $92 per ton at the mine whereas exports to Japan were priced at $66 per ton.[4]

### Table 7.—U.S. exports of sodium carbonate and sodium sulfate

(Thousand short tons and thousand dollars)

| Year | Sodium carbonate | | Sodium sulfate | |
|---|---|---|---|---|
| | Quantity | Value[1] | Quantity | Value[1] |
| 1982 | 1,109 | 140,616 | 111 | 12,162 |
| 1983 | 1,636 | 154,584 | 91 | 11,380 |
| 1984 | 1,648 | 160,774 | 76 | 9,587 |
| 1985 | [2]1,771 | [2]186,064 | 119 | 11,899 |

[1] Free alongside ship (f.a.s.) value at U.S. port.
[2] Adjusted by the Bureau of Mines to account for discrepancies in data.

Source: Bureau of the Census.

### Table 8.—U.S. imports for consumption of sodium sulfate

(Thousand short tons and thousand dollars)

| Year | Crude (salt cake)[1] | | Anhydrous | | Total[1] | |
|---|---|---|---|---|---|---|
| | Quantity | Value[2] | Quantity | Value[2] | Quantity | Value[2] |
| 1982 | 210 | 13,820 | 184 | 14,938 | 394 | 28,758 |
| 1983 | 144 | 10,312 | 199 | 17,609 | 343 | 27,921 |
| 1984 | 61 | 4,223 | 204 | 16,975 | 265 | 21,198 |
| 1985 | 40 | 2,549 | 154 | 11,943 | 194 | 14,492 |

[1] Includes Glauber's salt as follows: 1982—2 tons ($1,241); 1983—3 tons ($1,648); and 1984—12 tons ($4,997).
[2] Customs, insurance, and freight (c.i.f.) value at U.S. port.

Source: Bureau of the Census.

### Table 9.—U.S. imports for consumption of sodium carbonate

| | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (short tons) | Value[1] (thousands) | Quantity (short tons) | Value[1] (thousands) |
| Sodium carbonate, calcined | 16,659 | $2,292 | 56,198 | $8,085 |
| Sodium carbonate, hydrated, and sesquicarbonate | 5 | 9 | 4 | 4 |
| Total | 16,664 | 2,301 | 56,202 | 8,089 |

[1] Customs, insurance, and freight (c.i.f.) value at U.S. port.

Source: Bureau of the Census.

## WORLD REVIEW

**Egypt.**—At midyear, MISR Chemical Industries Co., the Nation's sole soda ash producer, elected Chemieanlagen Co. of the German Democratic Republic and Krebs and Co. of France as engineering contractors for the proposed expansion of production capacity at the El Mex synthetic soda ash facility. If completed, the project could increase total capacity from 80,000 tons to 200,000 tons per year.[5]

**India.**—The Government reduced duties from 70% to 35% on light soda ash imports and from 70% to 15% on dense soda ash imports. These duty reductions were in response to a surge in soda ash demand by the Indian detergent industry and soda ash supply problems. The light soda ash duty was expected to be reduced to 25% in early 1986. Less expensive imports were expected to ease the supply imbalance temporarily. In addition, in 1985 approval was granted to construct five new synthetic soda ash plants to increase India's production capability.[6]

**Turkey.**—Progress continued toward development of the Baypazari trona deposit as FMC and Etibank, the state-owned mining company, each agreed to have a 35% equity share in the venture; the International Bank for Reconstruction and Development held 10%, and private Turkish investors held the remainder. Turkey has been an associate member of the European Economic Community. Full member status by the early 1990's when the project is targeted for completion could provide FMC with a competitive advantage for supplying soda ash to western European markets.[7]

### Table 10.—Sodium carbonate: World production, by country[1]

(Short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Albania[e] | 27,600 | [r]29,700 | [r]30,800 | [r]33,000 | 34,100 |
| Australia[e] | 330,000 | 330,000 | 330,000 | 330,000 | 330,000 |
| Austria[e] | 190,000 | 190,000 | 190,000 | 165,000 | 165,000 |
| Belgium | 300,931 | 361,170 | 286,340 | 451,224 | 500,000 |
| Brazil | 207,234 | 219,360 | 231,485 | [e]210,000 | 210,000 |
| Bulgaria | 1,618,948 | 1,607,940 | 1,400,918 | [e]1,610,000 | 1,610,000 |
| Canada[e] | 500,000 | 500,000 | 470,000 | 400,000 | 385,000 |
| Chad[e] [2] | 5,500 | 5,500 | NA | NA | NA |
| Chile[e] | 11,000 | NA | NA | NA | NA |
| China | 1,821,016 | 1,911,406 | 1,976,442 | [e]2,070,000 | 2,200,000 |
| Colombia | [r]117,087 | 122,136 | 130,392 | 142,683 | 140,000 |
| Czechoslovakia | 130,293 | 117,313 | 104,694 | 111,711 | 110,000 |
| Denmark[3] | 164 | 131 | 159 | 139 | 138 |
| Egypt | 25,754 | 45,496 | 47,399 | [e]45,000 | 45,000 |
| France[e] | 1,765,000 | [r]1,100,000 | [r]1,100,000 | [r]990,000 | 990,000 |
| German Democratic Republic | 967,828 | 972,237 | 977,749 | 981,056 | 990,000 |
| Germany, Federal Republic of | 1,310,647 | 1,218,053 | 1,342,614 | 1,503,551 | 1,600,000 |
| Greece[e] | 1,100 | 1,100 | 1,100 | 1,100 | 1,100 |
| India | [e]676,000 | 646,836 | 820,481 | 915,869 | 850,000 |
| Italy[e] | 105,000 | 100,000 | 95,000 | 100,000 | 100,000 |
| Japan | 1,298,185 | 1,281,323 | 1,216,265 | 1,142,140 | 1,290,000 |
| Kenya[2] | 275,578 | 176,855 | 213,506 | 249,177 | 250,000 |
| Korea, Republic of | 222,736 | 204,666 | 254,193 | 273,292 | [4]276,559 |

See footnotes at end of table.

## Table 10.—Sodium carbonate: World production, by country[1] —Continued

(Short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Mexico[5] | 442,026 | 429,901 | [e]440,000 | 466,300 | [4]504,000 |
| Netherlands[e] | 460,000 | 460,000 | 460,000 | 440,000 | 440,000 |
| Norway | (6) | (6) | (6) | (6) | -- |
| Pakistan | [r]111,507 | [r]109,254 | [r] [e]112,400 | [r] [e]135,000 | 130,000 |
| Poland | 771,617 | 822,323 | 909,406 | 1,011,921 | 940,000 |
| Portugal[e] | 190,000 | 190,000 | 180,000 | 165,000 | 165,000 |
| Romania | 1,020,739 | 959,010 | 868,620 | 881,848 | 890,000 |
| Spain[e] | 550,000 | 550,000 | 550,000 | 610,000 | 610,000 |
| Sweden[e] | (6) | (6) | (6) | (6) | -- |
| Switzerland[e] | 51,000 | [r]50,000 | 50,000 | 49,000 | 50,000 |
| Taiwan | 79,437 | 65,279 | 103,419 | 118,179 | 110,000 |
| Turkey[e] | 65,000 | 65,000 | [r]65,000 | [r]65,000 | 65,000 |
| U.S.S.R | 5,357,227 | 5,250,303 | 5,620,679 | 5,639,418 | 5,730,000 |
| United Kingdom[e] | 1,430,000 | 1,430,000 | 1,430,000 | [r]1,100,000 | 1,100,000 |
| United States[5] | 8,281,495 | 7,819,083 | 8,467,118 | 8,511,359 | [4]8,597,180 |
| Yugoslavia | 162,212 | 200,488 | 202,135 | 207,555 | [4]220,053 |
| Total | [r]30,879,861 | [r]29,541,863 | 30,678,314 | 31,125,522 | 31,628,130 |

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1] Table includes data available through May 6, 1986. Synthetic unless otherwise specified.

[2] Natural only.

[3] Production for sale only; excludes output consumed by producers.

[4] Reported figure.

[5] Includes natural and synthetic.

[6] Revised to zero.

## Table 11.—Sodium sulfate: World production, by country[1]

(Thousand short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Natural: | | | | | |
| Argentina | 57 | 47 | 50 | [e]50 | 44 |
| Canada | 590 | 603 | 500 | [e]427 | 413 |
| Chile[3] | (4) | 1 | 1 | 1 | 1 |
| Egypt | [e]3 | 3 | 2 | [e]2 | 2 |
| Iran[e] | 11 | 11 | 13 | 13 | 13 |
| Mexico[5] | [r]465 | [r]519 | 436 | 456 | 463 |
| South Africa, Republic of | 5 | 3 | 1 | 1 | (4) |
| Spain | 207 | 232 | 345 | 405 | 364 |
| Turkey | 73 | 72 | 68 | 92 | 94 |
| U.S.S.R.[e] [6] | 386 | 397 | 397 | 397 | 408 |
| United States | 608 | [7]W | 423 | 435 | [8]389 |
| Total | [r]2,405 | [r]1,888 | 2,236 | 2,279 | 2,191 |
| Synthetic: | | | | | |
| Austria[e] | 61 | 61 | 61 | 55 | 55 |
| Belgium[e] | 276 | 276 | 276 | 276 | 287 |
| Chile[9] | 64 | 52 | 57 | 63 | 61 |
| Finland[e] | [r]44 | [r]44 | [r]39 | [r]39 | 39 |
| France[e] | 165 | 165 | 165 | [r]132 | 138 |
| German Democratic Republic | 141 | 157 | 168 | 181 | 182 |
| Germany, Federal Republic of | 281 | 236 | 138 | 141 | 149 |
| Greece | [r]11 | [r]8 | [r] [e]9 | [r] [e]10 | 10 |
| Hungary[e] | 11 | 11 | 11 | 11 | 11 |
| Italy[e] | 99 | 94 | 99 | [r]88 | 88 |
| Japan | 314 | 282 | 287 | 307 | 320 |
| Netherlands[e] | 55 | 55 | 55 | 50 | 50 |
| Portugal[e] | [8]64 | 63 | 62 | 55 | 55 |
| Spain[e] [10] | 193 | 187 | 187 | 187 | 176 |
| Sweden[e] | [r]110 | [r]110 | [r]110 | [r]110 | 110 |

See footnotes at end of table.

**Table 11.—Sodium sulfate: World production, by country[1] —Continued**

(Thousand short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Synthetic: —Continued | | | | | |
| U.S.S.R.[e] [6] | 276 | 276 | 276 | 276 | 287 |
| United States[11] | 503 | [7]864 | 432 | 437 | [8]438 |
| Total | [r]2,668 | [r]2,941 | 2,432 | 2,418 | 2,456 |
| Grand total | [r]5,073 | [r]4,829 | 4,668 | 4,697 | 4,647 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1] Table includes data available through May 6, 1986.

[2] In addition to the countries listed, China, Norway, Poland, Romania, Switzerland, and the United Kingdom are known to or are assumed to have produced synthetic sodium sulfate, and other unlisted countries may have produced this commodity, but production figures are not reported, and available general information is not adequate for the formulation of reliable estimates of output levels.

[3] Natural mine output, excluding byproduct output from the nitrate industry, which is reported separately under "Synthetic" in this table.

[4] Less than 1/2 unit.

[5] Series reflects output reported by Industrias Peñoles S.A. de C.V., Mexico's principal producer, plus an additional 22,000 short tons (estimated) by a smaller producer.

[6] Conjectural estimates based on 1968 information on natural sodium sulfate and general economic conditions.

[7] Natural sodium sulfate included with synthetic sodium sulfate production.

[8] Reported figure.

[9] Byproduct of nitrate industry.

[10] Quantities of synthetic sodium sulfate credited to Spain are reported in official sources in a way such as to indicate that they are in addition to the quantities reported as mined (reported in this table under "Natural"), but some duplication may exist.

[11] Derived approximate figures; data presented are the difference between reported total sodium sulfate production (natural and synthetic not differentiated) and reported natural sodium sulfate sold by producers (reported under "Natural" in this table).

## TECHNOLOGY

FMC designed and built a flue gas desulfurization unit that was installed at yearend, with the cooperation of the City of Colorado Springs Department of Utilities, on a coal-fired boiler at the Nixon powerplant in Fountain, CO. The scrubbing agent, sodium sesquicarbonate, reacted with sulfur oxide emissions from the burning coal to form sodium sulfite and sodium sulfate. Reducing sulfur oxide emissions by 70% is required to comply with new Environmental Protection Agency standards and Colorado air quality regulations. Eventually, sodium bicarbonate and trona also were to be tested as scrubbing agents. Proof of the economic effectiveness of any of these commodities as desulfurizing mediums could be a significant boon to the Wyoming soda ash industry, which has sustained stagnant or declining domestic soda ash demand.[8]

Ontario Paper Co. at Thorold, Ontario, Canada, developed a process to produce sodium bicarbonate as a byproduct of pulp and paper manufacturing. By reacting carbon dioxide with a solution containing sodium carbonate and sodium sulfate, which usually are recovered and recycled in a pulp and paper operation, the sodium carbonate was converted to sodium bicarbonate and the sodium sulfate could be separated subsequently by fractional crystallization. A substantial increase in domestic sodium bicarbonate demand could promote the use of this technique in U.S. pulp mills.[9]

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[1] Physical scientist, Division of Industrial Minerals.

[2] U.S. Senate. Barriers to U.S. Exports. Congr. Rec., v. 131, No. 177, Dec. 19, 1985, pp. S18380-S18385.

[3] Chemical Week. In New Cars, Plastics Are Taking the Driver's Seat. V. 137, No. 17, 1985, pp. 6-8.

[4] Glass Industry. Japanese Producers Charge Soda Ash Dumping. V. 66, No. 13, 1985, p. 10.

[5] Industrial Minerals (London). Egyptian Soda Ash Plant Retrofit. No. 216, 1985, p. 94.

[6] European Chemical News. V. 45, No. 1196, 1985, p. 9.

[7] Industrial Minerals (London). Soda Ash Progress. No. 220, 1986, p. 11.

[8] ———. Trona in Desulfurization. No. 222, 1986, p. 25.

[9] Corpus Chemical Report. Ontario Paper Considering Sodium Bicarbonate Project. V. 17, No. 38, Sept. 23, 1985, p. 1.

# Crushed Stone

## By Valentin V. Tepordei[1]

A total of 1.0 billion short tons of crushed stone valued at $4.1 billion, f.o.b. plant, was reported produced in the United States in 1985. The tonnage is 9% below the record-high production of 1979 but 5% higher than the estimated production of 1984. About three-quarters of the crushed stone production continued to be limestone and dolomite, followed by granite, traprock, sandstone and quartzite, shell, calcareous marl, volcanic cinder, marble, and slate, in order of volume.

Exports of crushed stone were unchanged from the 1984 level, while imports for consumption decreased 7%. Ninety-five percent of the exported and 48% of the imported crushed stone was limestone. Apparent consumption of crushed stone was 1.0 billion tons.

**Domestic Data Coverage.**—Domestic production data for crushed stone are developed by the Bureau of Mines from voluntary surveys of U.S. producers. Beginning with 1981, full surveys of crushed stone producers were conducted for odd-numbered years only. For even-numbered years, annual preliminary surveys, which collect production information on a sample basis, are conducted to generate annual estimates at the State level. This survey canvasses most of the large companies in each State producing up to 75% of that State's total tonnage.

**Table 1.—Salient U.S. crushed stone statistics**

(Thousand short tons and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Sold or used by producers: | | | | | |
| Quantity[1] | 872,600 | [e]790,030 | 861,600 | [e]956,000 | 1,000,800 |
| Value[1] | $3,125,000 | [e]$2,918,300 | $3,327,000 | [e]$3,755,600 | $4,053,000 |
| Exports (value) | $25,949 | $19,026 | $23,021 | $23,970 | $29,347 |
| Imports for consumption (value) | $13,473 | $16,382 | [2]$12,610 | [2]$17,543 | [2]$11,640 |

[e]Estimated. [r]Revised.

[1]Does not include American Samoa, Guam, Puerto Rico, and the Virgin Islands.

[2]Excludes precipitated calcium carbonate.

Of the 4,788 crushed stone operations surveyed by the Bureau of Mines in 1985, 3,557 were active. Of these, 3,147, or 88.5%, responded. Their total production represented 87.6% of the U.S. total crushed stone output. The nonrespondents' production was estimated using adjusted prior years production reports and/or employment data. Of the 3,147 reporting operations, some did not indicate a breakdown by end use. Their production as well as that of 1,350 nonrespondents, representing 19.1% of the U.S. total, is included in tables 11, 13, 15-18 under "Other unspecified uses." A total of 1,205 operations were either idle or presumed to be idle, because no information was available to estimate their production. A significant number of the idle quarries were operated by State and local governments, mostly to supply crushed stone for maintenance or road construction projects.

**Legislation and Government Programs.**—On March 5, the U.S. Congress approved the Interstate Cost Estimate (ICE) legislation that retroactively gave the U.S. Department of Transportation the authority to disburse to the States construction funds collected into the Federal Highway

Trust Fund for the period ending September 30, 1985. On September 19, 1985, additional ICE legislation was passed by the U.S. Congress for the period ending September 30, 1986. Most of these funds were used for highway construction and repair work, and their late release impacted to some extent upon the demand for crushed stone.

In August, the Environmental Protection Agency (EPA) issued its final regulations establishing particulate emission standards of performance for nonmetallic mineral processing plants. These regulations went into effect on August 1, 1985, and will be implemented under section III of the Clean Air Act. The standards were based on emission levels achievable using well-designed and operated baghouse controls or wet-dust suppression techniques. The standards apply to new, modified, and reconstructed facilities at plants processing 18 nonmetallic minerals, including crushed stone.

## DOMESTIC PRODUCTION

Of the total 1.0 billion tons of crushed stone produced in the United States, 716 million tons or 72% was limestone and dolomite, 145 million tons or 15% was granite, and 84 million tons or 8% was traprock. A comparison of the four major geographic regions indicated that in 1985, the South continued to lead the Nation in the production of crushed stone with 51% of the total, followed by the North Central with 25%, and the Northeast with 14%. Approximately 76% of the total U.S. crushed stone output was produced in two major geographic regions, the South and North Central.

Of the nine geographic regions, the South Atlantic led the Nation in the production of crushed stone with 266 million tons or 27% of the U.S. total. Next was the East North Central region with 148 million tons or 15% of the total, followed by the West South Central with 137 million tons or 14%.

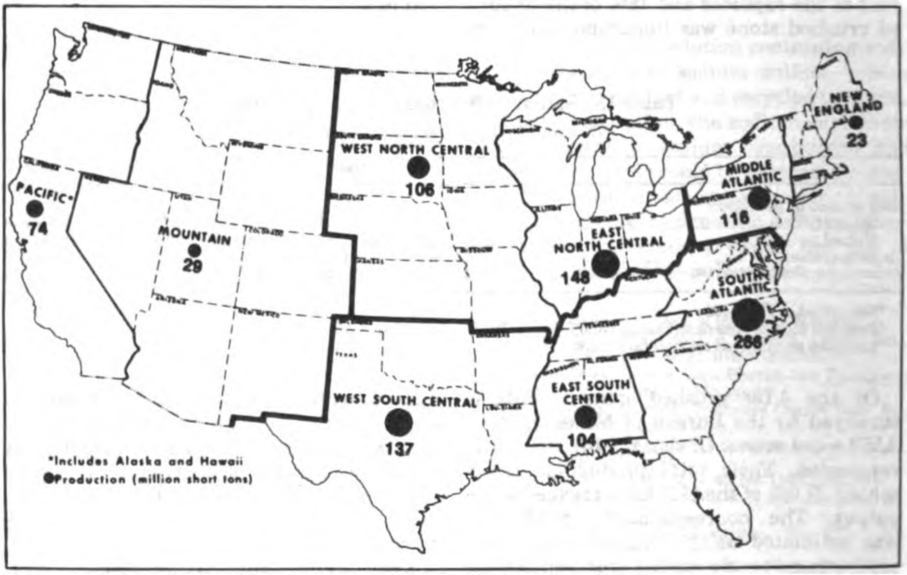

**Figure 1.—Production of crushed stone in the United States in 1985, by geographic region.**

A comparison of the estimated 1984 and reported 1985 production data by regions indicated that the output of crushed stone increased in all regions except the East North Central. The largest increases were recorded in Middle Atlantic, 12%; West North Central, 10%; and South Atlantic, 7%.

Based on 1980 census data on population, per capita crushed stone production in 1985 was 4.4 tons. At the regional level, per capita production was 6.7 tons in the South, followed by the North Central with 4.3 tons, the Northeast with 2.8 tons, and the West with 2.4 tons.

Crushed stone was produced in every State except Delaware. The 10 leading States in the production of crushed stone, in order of volume, were Texas, Florida, Pennsylvania, Georgia, Virginia, Missouri, North Carolina, California, Illinois, and Ohio. Their combined production represented 54% of the national total.

Production of crushed stone increased in 31 States, including 7 of the top 10. The increases, in order of volume, were significant in Missouri, Pennsylvania, and Georgia, while Illinois, Texas, and Ohio were the only high producing States that showed a decrease in output.

Most of the crushed stone produced came from quarries with an annual output larger than 300,000 tons. Of the total tonnage produced, 941 quarries, representing 26% of the total number of active operations, produced 80%; of these, 218 quarries with an annual output of more than 1,000,000 tons produced 40%. The number of large quarries and their share of the market continues to increase, while the number of small operations is on the decrease.

The 10 leading producers of crushed stone were, in descending order of tonnage: Vulcan Materials Co., Martin Marietta Aggregates, Koppers Co. Inc., Lone Star Industries Inc., Florida Rock Industries Inc., Genstar Stone Products Co., General Dynamics Corp., United States Steel Corp., Gifford-Hill & Co. Inc., and Dolese Bros. Inc.

Compared with 1983, the year when the last full survey of crushed stone producers was conducted, the underground mining of mostly limestone increased 7% to 47 million tons, while the number of active mines decreased from 120 to 108. By operating underground, a variety of problems usually connected with surface mining, especially in locations close to urban areas, such as environmental impacts and community acceptance, are significantly reduced.

Lone Star Industries sold its south Texas aggregate operations, which included one crushed stone quarry, four sand and gravel operations, and seven ready-mix concrete plants, to Pioneer Concrete of Texas Inc.

Genstar began a $9 million expansion program at its Texas, MD, quarry. The new facility, when completed in 1986, will increase production capacity by 50% and improve overall efficiency of the crushing operation. The expansion included a continuous crushing system and new state-of-the-art automated equipment for tertiary crushing. The entire system will be programmed by on-site minicomputers and will be one of the most advanced facilities in the industry. Crushed stone produced at this quarry is used primarily for construction purposes. A special section of the operation produces chemical-grade limestone for the paint, paper, plastics, and rubber industries.

**Limestone.**—Starting with the 1983 survey, a new canvassing procedure was implemented that is designed to collect separate information on the amount of limestone and dolomite produced in the United States. In 1985, 87 quarries reported producing only dolomite, while 46 quarries reported producing both limestone and dolomite without making a distinction between the two kinds of stone. Therefore, the limestone totals shown in this chapter include an undetermined amount of dolomite in addition to the dolomite reported separately. Compared with 1983, the 1985 output of crushed limestone, including dolomite, increased 15% to 716 million tons valued at $2.8 billion. Limestone and dolomite were produced by 1,117 companies at 2,316 quarries in 46 States. Leading States, in order of tonnage, were Texas, Florida, Pennsylvania, Missouri, and Illinois; these five States accounted for 40% of the total U.S. output. Leading U.S. producers were, in order of volume, Vulcan Materials, Martin Marietta Aggregates, and Lone Star Industries. These three companies accounted for 12% of total U.S. output.

**Dolomite.**—A total of 31 million tons of dolomite valued at $133 million was reported produced by 60 companies in 24 States. An additional undetermined amount of dolomite is included in the total crushed limestone data. Leading States in the production of dolomite, in order of tonnage, were New York, Pennsylvania, and Michigan; these three States accounted for 51% of the total U.S. output as reported by producers. Leading U.S. producers were, in order of volume, Lone Star Industries, ASARCO Incorporated, and Glasgow Inc.; their combined production represented 28% of the total U.S. dolomite production.

**Marble.**—Production of crushed marble increased 36% to 2.4 million tons valued at $20 million. Crushed marble was produced by 12 companies at 22 quarries in 13 States. Leading States, in order of tonnage, were Georgia, Alabama, and Texas; these three

States accounted for 91% of the total U.S. output. Leading producers of crushed marble, in order of tonnage, were Georgia Marble Co., Thompson-Weinsman Co., and Basins Engineering Co.; their combined production represented 84% of the total U.S. output.

**Calcareous Marl.**—Output of marl increased 15% to 4 million tons valued at $8 million. Marl was produced by 14 companies at 14 quarries in 7 States. South Carolina accounted for 80% of total U.S. output, followed by Texas and North Carolina. Leading producers, in order of tonnage, were Dundee Cement Co., Giant Portland Cement Co., and Gifford-Hill; their combined output accounted for 80% of the total U.S. production. These three leading producers of marl were also manufacturers of portland cement.

**Shell.**—Shell is mainly derived from fossil reefs of oyster shell. The output of crushed shell increased 9% to 9 million tons valued at $38 million. Crushed shell was produced by 13 companies from 17 operations in 5 States. The major producing States were Louisiana and Florida. Leading producers, in order of tonnage, were Dravo Corp., Quality Aggregates, and Ashland Oil Inc.; their combined production represented 63% of U.S. output.

**Granite.**—Compared with 1983, the 1985 output of crushed granite increased 24% to 145 million tons valued at $670 million. Granite was produced by 130 companies at 580 quarries in 29 States. Leading States, in order of tonnage, were Georgia, North Carolina, Virginia, South Carolina, and California; these five States accounted for 81% of U.S. output. Leading U.S. producers, in order of tonnage, were Vulcan Materials, Martin Marietta Aggregates, and Koppers; their combined production represented 48% of the U.S. total.

**Traprock.**—Production of crushed traprock increased 13% to 84 million tons valued at $388 million. Traprock was produced by 242 companies at 644 quarries in 23 States. Leading States, in order of tonnage, were New Jersey, Oregon, California, Washington, and Virginia; these five States accounted for 58% of U.S. output. Leading U.S. producers, in order of tonnage, were Tilcon Inc., Traprock Industries Inc., and the U.S. Forest Service; their combined production accounted for 19% of total U.S. output.

**Sandstone and Quartzite.**—The combined output of crushed sandstone and quartzite increased 9% to 23 million tons valued at $103 million. Crushed sandstone was produced by 103 companies at 361 quarries in 24 States, while crushed quartzite was produced by 16 companies at 17 quarries in 12 States. Leading States in the production of sandstone and quartzite, in order of volume, were Pennsylvania, Arkansas, and Georgia. Leading producers, in order of tonnage, were Weaver Construction Co., the U.S. Forest Service, and H. M. B. Construction Co.; their combined production represented 14% of the U.S. total.

**Slate.**—Output of crushed slate increased 1% to 773,000 tons valued at $3.8 million. Crushed slate was produced by seven companies at seven quarries in five States. Leading States, in order of tonnage, were Virginia, Georgia, and New York; their combined production accounted for 90% of U.S. output. Leading producers, in order of tonnage, were Galite Corp., Solite Corp., and Arvonia-Buckingham Slate Co. The top three producers accounted for 80% of U.S. output.

**Volcanic Cinder and Scoria.**—Production of volcanic cinder and scoria increased 61% to 3 million tons valued at $12.5 million. Volcanic cinder and scoria were produced by 38 companies from 256 operations in 10 States. Leading States, in order of volume, were Oregon, Arizona, and California; their combined production accounted for 62% of the total U.S. output. Leading producers, in order of tonnage, were the U.S. Forest Service and Gilbert Central Corp.; their combined production accounted for 29% of U.S. output.

**Miscellaneous Stone.**—Output of miscellaneous crushed stone increased 28% to 13 million tons valued at $56.9 million.

## Table 2.—Crushed stone sold or used in the United States, by kind

| Kind | 1983 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Number of quarries | Quantity (thousand short tons) | Value (thousands) | Unit value | Number of quarries | Quantity (thousand short tons) | Value (thousands) | Unit value |
| Limestone | [r]2,476 | [r]599,308 | [r]$2,217,216 | [r]$3.69 | 2,316 | 685,002 | $2,618,621 | $3.82 |
| Dolomite | [r]79 | [r]23,807 | [r]99,673 | [r]4.18 | 87 | 31,348 | 133,271 | 4.25 |
| Marble | [r]24 | [r]1,798 | [r]29,613 | [r]16.46 | 22 | 2,437 | 20,439 | 8.39 |
| Calcareous marl | 20 | 3,451 | 7,937 | [r]2.29 | 14 | 3,959 | 8,083 | 2.04 |
| Shell | 19 | 8,348 | 33,314 | 3.99 | 17 | 9,106 | 37,951 | 4.16 |
| Granite | 509 | [r]116,678 | [r]487,017 | [r]4.17 | 580 | 145,254 | 669,807 | 4.61 |
| Traprock | [r]587 | [r]74,017 | [r]305,509 | [r]4.12 | 644 | 83,548 | 388,027 | 4.64 |
| Sandstone and quartzite | 300 | 21,259 | [r]87,945 | [r]4.13 | 378 | 23,148 | 103,483 | 4.47 |
| Slate | 8 | [r]763 | [r]8,383 | [r]10.98 | 7 | 773 | 3,758 | 4.86 |
| Volcanic cinder and scoria | 186 | 1,832 | 9,149 | 4.99 | 256 | 2,953 | 12,504 | 4.23 |
| Miscellaneous stone | [r]183 | [r]10,384 | [r]41,225 | [r]3.97 | 81 | 13,269 | 56,875 | 4.29 |
| Total[1] | XX | 861,600 | 3,827,000 | [r]3.86 | XX | 1,000,800 | 4,053,000 | 4.05 |

[r] Revised. XX Not applicable.

[1] Data may not add to totals shown because of independent rounding.

## Table 3.—Crushed stone[1] sold or used in the United States, by region

(Thousand short tons and thousand dollars)

| Region | 1984[e] | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Northeast: | | | | |
| New England | 21,650 | 108,300 | 22,540 | 112,910 |
| Middle Atlantic | 102,800 | 438,000 | 115,595 | 570,333 |
| North Central: | | | | |
| East North Central | 157,600 | 567,000 | 147,923 | 520,118 |
| West North Central | 96,200 | 347,500 | 106,035 | 369,972 |
| South: | | | | |
| South Atlantic | 248,800 | 1,077,800 | 265,665 | 1,169,994 |
| East South Central | 97,500 | 375,300 | 103,525 | 404,456 |
| West South Central | 134,000 | 465,300 | 136,929 | 495,687 |
| West: | | | | |
| Mountain | 28,050 | 108,700 | 28,971 | 106,938 |
| Pacific | 69,400 | 267,700 | 73,612 | 302,409 |
| Total[2] | 956,000 | 3,755,600 | 1,000,800 | 4,053,000 |

[e] Estimated.

[1] Includes volcanic cinder and scoria.

[2] Data may not add to totals shown because of independent rounding.

## Table 4.—Crushed stone sold or used by producers in the United States, by State[1]

(Thousand short tons and thousand dollars)

| State | 1984[e] |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value |
| Alabama | 22,000 | 98,500 | 25,853 | 109,176 |
| Alaska | 2,500 | 10,800 | 1,907 | 8,535 |
| Arizona | 5,200 | 27,300 | 5,929 | 23,111 |
| Arkansas | 15,200 | 59,800 | 14,815 | 60,874 |
| California | 38,600 | 158,000 | 41,199 | 174,395 |
| Colorado | 7,200 | 26,200 | 7,037 | 25,930 |
| Connecticut | 8,300 | 49,400 | 7,277 | 43,937 |
| Florida | 68,500 | 290,000 | 69,266 | 287,237 |
| Georgia | 45,900 | 220,000 | 52,062 | 256,588 |
| Hawaii | 5,400 | 29,700 | 5,627 | 34,183 |
| Idaho | 1,800 | 7,100 | 2,019 | 6,977 |
| Illinois | 48,500 | 191,600 | 41,044 | 164,117 |
| Indiana | 26,700 | 99,400 | [2]23,384 | [2]81,117 |
| Iowa | 23,800 | 100,000 | 23,657 | 94,496 |
| Kansas | 13,600 | 48,500 | 15,653 | 57,155 |
| Kentucky | 37,300 | 133,000 | [3]38,022 | [3]134,978 |
| Louisiana | 4,100 | 19,500 | [4]4,820 | [4]25,956 |
| Maine | 1,300 | 4,400 | 1,459 | 5,114 |
| Maryland | 22,100 | 94,000 | 24,406 | 98,584 |
| Massachusetts | 8,400 | 39,000 | 9,354 | 42,881 |
| Michigan | 28,100 | 92,000 | 30,685 | 95,953 |
| Minnesota | 8,900 | 25,800 | 7,756 | 22,601 |
| Mississippi | 2,000 | 5,800 | 1,582 | 4,282 |
| Missouri | 41,600 | 137,000 | 50,646 | 162,097 |
| Montana | 950 | 2,400 | [5]1,730 | [5]5,044 |
| Nebraska | 4,500 | 23,400 | 4,175 | 19,134 |
| Nevada | 1,100 | 4,700 | 1,334 | 6,218 |
| New Hampshire | 850 | 2,700 | 1,612 | 6,434 |
| New Jersey | 13,500 | 75,000 | 15,692 | 94,339 |
| New Mexico | 4,700 | 17,000 | 3,641 | 15,232 |
| New York | 33,100 | 135,000 | 35,139 | 165,136 |
| North Carolina | 38,100 | 168,000 | 41,771 | 194,818 |
| North Dakota | -- | -- | W | W |
| Ohio | 38,500 | 139,000 | 38,310 | 136,544 |
| Oklahoma | 25,500 | 86,000 | 31,173 | 98,811 |
| Oregon | 12,500 | 37,500 | 15,336 | 54,244 |
| Pennsylvania | 56,200 | 228,000 | 64,765 | 310,859 |
| Rhode Island | 1,000 | 5,800 | [4]1,135 | [4]7,016 |
| South Carolina | 17,900 | 72,500 | 17,079 | 72,520 |
| South Dakota | 3,800 | 12,800 | 4,071 | 14,412 |
| Tennessee | 36,200 | 138,000 | [6]37,939 | [6]155,760 |
| Texas | 89,200 | 300,000 | 85,764 | 306,821 |
| Utah | 5,200 | 16,400 | 4,657 | 14,180 |
| Vermont | 1,800 | 7,000 | 1,689 | 7,468 |
| Virginia | 47,200 | 196,000 | 51,686 | 221,900 |
| Washington | 10,400 | 31,700 | 9,543 | 31,052 |
| West Virginia | 9,100 | 37,300 | 9,393 | 38,348 |
| Wisconsin | 15,800 | 45,000 | 14,496 | 42,380 |
| Wyoming | 1,900 | 7,600 | [6]2,030 | [6]7,329 |
| Other | -- | -- | 1,177 | 6,545 |
| Total[7] | 956,000 | 3,755,600 | 1,000,800 | 4,053,000 |

[e] Estimated. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] To avoid disclosing company proprietary data, certain State totals do not include all kinds of stone produced within the State; the portion not shown has been included with "Other."

[2] Excludes marl.

[3] Excludes sandstone.

[4] Excludes other stone.

[5] Excludes traprock.

[6] Excludes granite.

[7] Data may not add to totals shown because of independent rounding.

### Table 5.—U.S. crushed stone sold or used by producers in 1985, by size of operation

| Size range (thousand short tons) | Number of operations | Quantity (thousand short tons) | Percent |
|---|---|---|---|
| 0 to 25 | 931 | 9,233 | 0.9 |
| 25 to 50 | 463 | 16,597 | 1.7 |
| 50 to 75 | 272 | 16,789 | 1.7 |
| 75 to 100 | 182 | 15,832 | 1.6 |
| 100 to 200 | 506 | 76,825 | 7.6 |
| 200 to 300 | 262 | 64,040 | 6.4 |
| 300 to 400 | 192 | 65,828 | 6.6 |
| 400 to 500 | 156 | 69,257 | 6.9 |
| 500 to 600 | 117 | 63,940 | 6.4 |
| 600 to 700 | 79 | 50,765 | 5.0 |
| 700 to 800 | 76 | 56,157 | 5.6 |
| 800 to 900 | 64 | 53,737 | 5.4 |
| 900 to 999 | 39 | 36,740 | 3.7 |
| 1,000 and over | 218 | 405,057 | 40.5 |
| Total | 3,557 | [1]1,000,800 | 100 |

[1] Data do not add to total shown because of independent rounding.

### Table 6.—Crushed limestone and dolomite sold or used in the United States in 1985, by State

(Thousand short tons and thousand dollars)

| State | Quantity | Value |
|---|---|---|
| Alabama | 24,770 | 98,723 |
| Alaska | W | W |
| Arizona | 3,749 | 15,626 |
| Arkansas | 4,940 | 17,200 |
| California | 17,233 | 77,687 |
| Colorado | 3,035 | 9,644 |
| Connecticut | 308 | 1,356 |
| Florida | 65,326 | 278,088 |
| Georgia | 6,992 | 31,484 |
| Hawaii | 1,006 | 6,927 |
| Idaho | 1,200 | 3,286 |
| Illinois | 41,044 | 164,117 |
| Indiana | 23,384 | 81,119 |
| Iowa | 23,657 | 94,496 |
| Kansas | 15,082 | 53,546 |
| Kentucky | 38,022 | 134,978 |
| Maine | 1,089 | 3,985 |
| Maryland | 15,810 | 56,262 |
| Massachusetts | W | W |
| Michigan | 30,604 | 95,810 |
| Minnesota | 5,692 | 17,057 |
| Mississippi | 1,582 | 4,282 |
| Missouri | 48,609 | 157,700 |
| Montana | 1,675 | 4,846 |
| Nebraska | 4,175 | 19,134 |
| Nevada | 1,096 | 4,832 |
| New Jersey | W | W |
| New Mexico | 2,131 | 8,200 |
| New York | 31,332 | 140,569 |
| North Carolina | 4,809 | 25,325 |
| Ohio | 38,217 | 136,092 |
| Oklahoma | 29,192 | 92,962 |
| Oregon | W | 4,082 |
| Pennsylvania | 50,933 | 248,314 |
| Rhode Island | 700 | 4,763 |
| South Carolina | 3,523 | 16,098 |
| South Dakota | 3,032 | 8,981 |
| Tennessee | 37,936 | 155,638 |
| Texas | 82,935 | 290,774 |
| Utah | 4,364 | 13,389 |
| Vermont | 1,311 | 5,699 |
| Virginia | 19,116 | 76,362 |
| Washington | 1,556 | 4,156 |
| West Virginia | 8,220 | 33,383 |
| Wisconsin | 12,030 | 35,369 |
| Wyoming | 1,643 | 6,063 |
| Other | 3,284 | 13,486 |
| Total[1] | 716,400 | 2,751,900 |

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Data may not add to totals shown because of independent rounding.

## Table 7.—Crushed calcareous marl sold or used by producers in the United States in 1985, by State

(Thousand short tons and thousand dollars)

| State | Quantity | Value |
|---|---|---|
| Florida | W | W |
| Indiana | W | W |
| Maine | W | W |
| Michigan | W | W |
| North Carolina | 37 | 135 |
| South Carolina | 3,171 | 6,642 |
| Texas | W | W |
| Other | 750 | 1,307 |
| Total[1] | 3,959 | 8,083 |

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Data may not add to totals shown because of independent rounding.

## Table 8.—Crushed granite, traprock, and sandstone and quartzite sold or used by producers in the United States in 1985, by State

(Thousand short tons and thousand dollars)

| State | Granite | | Traprock | | Sandstone and quartzite | |
|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value |
| Alabama | 267 | 1,165 | -- | -- | -- | -- |
| Alaska | 430 | 2,112 | 586 | 2,201 | 129 | 759 |
| Arizona | 1,307 | 3,983 | -- | -- | -- | -- |
| Arkansas | W | W | -- | -- | 4,017 | 15,414 |
| California | 8,156 | 31,827 | 9,733 | 41,523 | 1,051 | 4,116 |
| Colorado | 3,513 | 13,967 | W | W | 284 | 1,120 |
| Connecticut | -- | -- | 6,970 | 42,581 | -- | -- |
| Georgia | 41,263 | 206,508 | -- | -- | W | W |
| Hawaii | -- | -- | 4,487 | 26,786 | -- | -- |
| Idaho | 150 | 823 | 375 | 1,141 | 287 | 1,727 |
| Kansas | -- | -- | -- | -- | 565 | 3,564 |
| Kentucky | -- | -- | -- | -- | W | W |
| Maine | -- | -- | W | W | W | W |
| Maryland | 2,660 | 13,924 | W | W | W | W |
| Massachusetts | 1,743 | 10,231 | 6,504 | 26,140 | -- | -- |
| Michigan | -- | -- | W | W | -- | -- |
| Minnesota | 1,916 | 4,859 | 22 | 86 | W | W |
| Missouri | W | W | -- | -- | W | W |
| Montana | -- | -- | W | W | W | 198 |
| Nevada | W | W | -- | -- | -- | -- |
| New Hampshire | 515 | 2,430 | 1,097 | 4,004 | -- | -- |
| New Jersey | W | W | 12,064 | 68,748 | -- | -- |
| New Mexico | W | W | 293 | 951 | W | W |
| New York | W | W | 2,878 | 20,083 | 614 | 4,001 |
| North Carolina | 33,689 | 152,988 | 2,984 | 15,230 | W | W |
| Ohio | -- | -- | -- | -- | 93 | 452 |
| Oklahoma | W | W | -- | -- | 632 | 2,214 |
| Oregon | 90 | 342 | 12,050 | 42,528 | 1,089 | 4,333 |
| Pennsylvania | W | W | 5,696 | 23,766 | 4,847 | 24,890 |
| Rhode Island | 435 | 2,253 | -- | -- | -- | -- |
| South Carolina | 10,385 | 49,780 | -- | -- | -- | -- |
| South Dakota | W | W | -- | -- | 1,039 | 5,431 |
| Tennessee | W | W | -- | -- | -- | -- |
| Texas | W | W | 782 | 3,838 | 951 | 5,871 |
| Utah | -- | -- | -- | -- | 197 | 476 |
| Vermont | W | W | -- | -- | -- | -- |
| Virginia | 23,681 | 105,410 | 7,055 | 34,222 | 1,112 | 4,309 |
| Washington | 185 | 668 | 7,434 | 24,674 | 218 | 1,128 |
| West Virginia | -- | -- | -- | -- | 1,173 | 4,965 |
| Wisconsin | 667 | 2,158 | 19 | 53 | 1,781 | 4,801 |
| Wyoming | W | W | -- | -- | -- | -- |
| Other | 14,204 | 64,379 | 2,522 | 9,471 | 3,067 | 12,775 |
| Total[1] | 145,300 | 669,800 | 83,550 | 388,000 | 23,150 | 103,500 |

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1] Data may not add to totals shown because of independent rounding.

## Table 9.—Volcanic cinder and scoria and miscellaneous crushed stone sold or used by producers in the United States in 1985, by State

(Thousand short tons and thousand dollars)

| State | Volcanic cinder and scoria | | Miscellaneous stone | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Alaska | -- | -- | W | W |
| Arizona | 628 | 1,771 | W | W |
| California | W | W | 4,473 | 15,652 |
| Colorado | W | W | 7 | 27 |
| Hawaii | 133 | 469 | ([1]) | ([1]) |
| Kansas | -- | -- | 6 | 45 |
| Louisiana | -- | -- | W | W |
| Maryland | -- | -- | 3,286 | 16,628 |
| Massachusetts | -- | -- | W | W |
| Michigan | -- | -- | W | W |
| Nevada | 84 | 448 | W | W |
| New Mexico | 379 | 2,042 | -- | -- |
| New York | -- | -- | W | W |
| North Carolina | -- | -- | W | W |
| North Dakota | -- | -- | W | W |
| Oklahoma | -- | -- | 203 | 437 |
| Oregon | 672 | 2,375 | 229 | 584 |
| Pennsylvania | -- | -- | W | W |
| Rhode Island | -- | -- | W | W |
| Texas | -- | -- | 283 | 2,315 |
| Utah | 96 | 314 | ([1]) | 2 |
| Vermont | -- | -- | W | W |
| Virginia | -- | -- | W | W |
| Washington | ([1]) | 2 | 150 | 425 |
| Wyoming | 305 | W | -- | -- |
| Other | 655 | 5,084 | 4,632 | 20,761 |
| Total[2] | 2,953 | 12,500 | 13,270 | 56,880 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

## Table 10.—Kind of crushed stone produced in the United States in 1985, by State

| State | Limestone | Dolomite | Marble | Marl | Shell | Granite | Traprock | Sandstone | Quartzite | Slate | Volcanic cinder and scoria | Miscellaneous |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alabama | X | X | X |  |  | X |  |  |  |  |  | X |
| Alaska | X |  |  |  | X | X | X |  |  |  |  | X |
| Arizona | X | X | X |  |  | X |  | X |  | X | X |  |
| Arkansas | X | X |  |  |  | X |  | X |  |  |  |  |
| California | X | X |  |  | X | X | X | X | X |  | X | X |
| Colorado | X |  |  |  |  | X | X | X |  |  | X | X |
| Connecticut | X |  |  |  |  |  | X |  |  |  |  |  |
| Florida | X | X |  | X | X |  |  |  |  | X |  |  |
| Georgia | X | X | X |  |  | X |  |  | X |  |  |  |
| Hawaii | X |  |  |  |  |  | X |  |  |  | X | X |
| Idaho | X | X |  |  |  | X | X | X | X |  |  |  |
| Illinois | X | X |  |  |  |  |  |  |  |  |  |  |
| Indiana | X | X |  | X |  |  |  |  |  |  |  |  |
| Iowa | X |  |  |  |  |  |  |  |  |  |  |  |
| Kansas | X |  |  |  |  |  |  | X | X |  |  | X |
| Kentucky | X |  |  |  |  |  |  | X |  |  |  |  |
| Louisiana |  |  |  |  | X |  |  |  |  |  |  | X |
| Maine | X |  |  | X |  |  | X | X |  |  |  |  |
| Maryland | X |  |  |  | X | X | X | X |  |  |  | X |
| Massachusetts | X |  |  |  |  | X | X |  |  |  |  | X |
| Michigan | X | X |  | X |  |  | X |  |  |  |  | X |
| Minnesota | X | X |  |  |  | X | X | X | X |  |  |  |
| Mississippi | X |  |  |  |  |  |  |  |  |  |  |  |
| Missouri | X | X | X |  |  | X |  | X |  |  |  |  |
| Montana | X |  |  |  |  |  | X | X | X |  |  |  |
| Nebraska | X |  |  |  |  |  |  |  |  |  |  |  |
| Nevada | X | X |  |  |  | X |  |  |  |  | X | X |
| New Hampshire |  |  |  |  |  | X | X |  |  |  |  |  |
| New Jersey | X |  |  |  |  | X | X |  |  |  |  |  |
| New Mexico | X |  |  |  |  | X | X |  | X | X | X |  |
| New York | X | X |  |  |  | X | X | X |  | X |  | X |
| North Carolina | X |  |  | X |  | X | X |  | X |  |  | X |
| North Dakota |  |  |  |  |  |  |  |  |  |  |  | X |
| Ohio | X | X |  |  |  |  |  | X | X |  |  |  |
| Oklahoma | X | X |  |  |  | X |  | X |  |  |  | X |
| Oregon | X |  |  |  |  | X | X | X |  |  | X | X |
| Pennsylvania | X | X |  |  |  | X | X | X |  |  |  | X |
| Rhode Island | X |  |  |  |  | X |  |  |  |  |  | X |
| South Carolina | X |  |  | X |  | X |  |  |  |  |  |  |
| South Dakota | X |  |  |  |  |  |  | X | X |  |  |  |
| Tennessee | X | X | X |  |  | X |  |  |  |  |  |  |
| Texas | X | X | X | X |  |  | X | X |  |  |  | X |
| Utah | X | X |  |  |  |  |  | X | X |  | X | X |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Vermont | X | | X | X | | | | | | X |
| Virginia | X | X | | X | X | X | | X | | X |
| Washington | X | X | | X | X | X | X | | X | X |
| West Virginia | X | | | | | X | | | | |
| Wisconsin | X | X | | X | X | X | | | | |
| Wyoming | X | X | X | X | | | | | X | |
| American Samoa | | | | | X | | | | | |
| Guam | X | | | | | | | | | |
| Puerto Rico | X | | X | X | X | | | | | X |

## CONSUMPTION AND USES

Crushed stone production reported to the Bureau of Mines is actually material "sold or used" by the producers. Stockpiled production is not reported. Therefore, the sold or used tonnage represents the amount of production released for domestic consumption or export in a given year. Because some of the crushed stone producers did not report a breakdown by end use, their total production as well as the estimated production of nonrespondents, was included in the tables under "Other unspecified uses," starting with the 1983 survey. This change in the processing procedures should be taken into account when 1983 and 1985 use patterns are compared with prior years.

In 1985, U.S. consumption of crushed stone was 1.0 billion tons valued at $4.1 billion, a 5% increase over the estimated consumption of 1984, and a 16% increase over the reported consumption of 1983. About 63% of this tonnage was used as construction aggregates, mostly for highway and road construction and maintenance, 11% for cement and lime manufacturing, 3% for agricultural purposes, 1% for metallurgical purposes, 2% for a variety of industrial uses, and 20% for other miscellaneous or unspecified uses.

**Limestone.**—Of the 685 million tons of crushed limestone consumed, 57% was used as construction aggregates, 16% for cement and lime manufacturing, and 3% for agricultural purposes. No significant changes occurred in the use patterns of crushed limestone at the national level, except for the large increase of the amount included in table 12 under "Other unspecified uses."

U.S. consumption of crushed limestone for total construction aggregates increased 10%, from 353 million tons in 1983, to 388 million tons in 1985. U.S. consumption of limestone for concrete aggregates decreased 6%, while limestone used as roadstone and coverings increased 3%. Among the major producing States, consumption of limestone as concrete aggregates increased in Florida, Kentucky, Texas, and Virginia, and decreased in Alabama, Illinois, Ohio, and Pennsylvania. Consumption of limestone as roadstone and coverings increased in Florida, Ohio, Pennsylvania, and Tennessee, but decreased in Illinois, Texas, and Wisconsin.

U.S. consumption of limestone and dolomite for cement manufacturing increased 17%, from 79 million tons in 1983, to 92 million tons in 1985. Among the major producing States, consumption of crushed limestone and dolomite for cement manufacturing increased in California, Michigan, Missouri, Pennsylvania, and Texas. U.S. consumption of limestone and dolomite for lime manufacturing decreased 18%, from 22 million tons in 1983, to 18 million tons in 1985. Among the major producing States, consumption of limestone and dolomite for lime manufacturing increased in Michigan and Texas, but decreased in Alabama, Kentucky, and Pennsylvania. U.S. consumption of aglime increased 17%, from 21 million tons in 1983, to 25 million tons in 1985. Among major producing States, consumption of aglime increased in Florida, Illinois, Kentucky, and Missouri, but decreased in Indiana, Iowa, and Pennsylvania.

**Dolomite.**—Of the 31 million tons of crushed dolomite consumed, 52% was used as construction aggregates, 9% as flux stone, 5% as aglime, and 2% for lime manufacturing. An additional amount of dolomite consumed in a variety of uses is reported with the limestone.

**Marble.**—Of the 2.4 million tons of crushed marble consumed, 52% was used as fillers and extenders and 35% was used for construction purposes. No other significant changes in the end-use pattern of crushed marble occurred.

**Granite.**—Of the 145 million tons of crushed granite consumed, 83% was used as construction aggregates and 7% was used as railroad ballast. Compared with 1983, consumption of both construction aggregates and railroad ballast increased 33% and 10%, respectively.

**Traprock.**—Of the 84 million tons of crushed traprock consumed, 71% was used as construction aggregates and 3% was used as railroad ballast.

**Sandstone and Quartzite.**—Of the 23 million tons of crushed sandstone and quartzite consumed, 63% was used as construction aggregates, some as railroad ballast, and 2% for cement and lime manufacturing. Compared with 1983, consumption of sandstone and quartzite as construction aggregates increased 37%, while consumption for cement manufacturing decreased 6%.

**Slate.**—Of the 773,000 tons of slate consumed, 51% was used as construction aggregates and the remaining 49% was used for a variety of industrial applications.

**Calcareous Marl.**—Of the 4.0 million tons consumed in 1985, 98% was used for cement manufacturing and 1% was used for agricultural purposes.

**Shell.**—Of the 9.1 million tons of crushed shell consumed, 69% was used as construction aggregates, mostly for roads, with cement and lime manufacturing as the next major use.

**Volcanic Cinder and Scoria.**—Of the 2.9 million tons of volcanic cinder and scoria consumed, 45% was used as construction aggregates, mainly for road construction and maintenance, and 15% was used as lightweight aggregate.

**Miscellaneous Stone.**—Of the 13.3 million tons of miscellaneous crushed stone consumed, 95% was used as construction aggregates, mainly for road construction and maintenance.

### Table 11.—Crushed stone sold or used by producers in the United States in 1985, by use

(Thousand short tons and thousand dollars)

| Use | Quantity | Value |
|---|---|---|
| Coarse aggregate (+1-1/2 inch): | | |
| Macadam | 14,860 | 57,354 |
| Riprap and jetty stone | 21,449 | 89,377 |
| Filter stone | 6,202 | 26,376 |
| Other coarse aggregate | 1,043 | 4,795 |
| Coarse aggregate, graded: | | |
| Concrete aggregate, coarse | 106,526 | 507,642 |
| Bituminous aggregate, coarse | 63,635 | 287,531 |
| Bituminous surface treatment aggregate | 25,462 | 120,831 |
| Railroad ballast | 23,257 | 91,177 |
| Other graded coarse aggregate | 736 | 2,698 |
| Fine aggregate (-3/8 inch): | | |
| Stone sand, concrete | 21,526 | 108,247 |
| Stone sand, bituminous mix or seal | 13,641 | 54,842 |
| Screening, undesignated | 19,797 | 81,076 |
| Other fine aggregate | 3,602 | 12,542 |
| Coarse and fine aggregate: | | |
| Graded road base or subbase | 175,952 | 647,320 |
| Unpaved road surfacing | 41,924 | 159,394 |
| Terrazzo and exposed aggregate | 3,281 | 22,676 |
| Crusher run or fill or waste | 67,892 | 272,633 |
| Other coarse and fine aggregate | 964 | 3,632 |
| Other construction materials[1] | 20,160 | 82,425 |
| Agricultural: | | |
| Agricultural limestone | 22,430 | 96,712 |
| Poultry grit and mineral food | 1,972 | 16,304 |
| Other agricultural uses | 485 | 2,458 |
| Chemical and metallurgical: | | |
| Cement manufacture | 96,586 | 258,953 |
| Lime manufacture | 17,343 | 67,385 |
| Dead-burned dolomite manufacture | 966 | 6,442 |
| Flux stone | 10,343 | 41,788 |
| Chemical stone | 604 | 2,655 |
| Glass manufacture | 404 | 3,500 |
| Sulfur oxide removal | 1,459 | 5,889 |
| Special: | | |
| Mine dusting or acid water treatment | 732 | 5,194 |
| Asphalt fillers or extenders | 811 | 5,292 |
| Whiting or whiting substitute | 1,091 | 17,266 |
| Other fillers or extenders | 4,533 | 50,266 |
| Abrasives | 312 | 1,309 |
| Lightweight aggregate | 803 | 3,158 |
| Roofing granules | 2,543 | 14,349 |
| Sugar refining | 267 | 781 |
| Paper manufacture | 685 | 2,031 |
| Other miscellaneous uses | 12,998 | 66,506 |
| Other unspecified uses[2] | 191,521 | 752,012 |
| Total[3] | 1,000,800 | 4,053,000 |

[1] Includes building products, dam construction, and drain fields.

[2] Includes production reported without a breakdown by use and estimates for nonrespondents.

[3] Data may not add to totals shown because of independent rounding.

## Table 12.—Crushed limestone and dolomite sold or used by

(Thousand short tons

| State | Concrete aggregate | | Bituminous aggregate | | Roadstone and coverings | | Riprap and railroad ballast | |
|---|---|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| Alabama | 2,546 | 11,694 | 4,334 | 17,949 | 2,399 | 10,057 | 877 | 3,151 |
| Alaska | -- | -- | -- | -- | W | W | -- | -- |
| Arizona | W | W | -- | -- | -- | -- | W | W |
| Arkansas | W | W | 306 | 1,359 | 388 | 1,221 | 583 | 2,282 |
| California | 1,007 | 4,114 | W | W | 1,210 | 6,125 | W | W |
| Colorado | -- | -- | -- | -- | -- | -- | -- | -- |
| Connecticut | -- | -- | -- | -- | -- | -- | -- | -- |
| Florida | 21,160 | 122,485 | 5,183 | 25,312 | 13,448 | 36,544 | 446 | 2,358 |
| Georgia | W | W | W | W | 1,691 | 7,733 | W | W |
| Hawaii | 386 | 3,807 | -- | -- | 103 | 799 | -- | -- |
| Idaho | 40 | 115 | 150 | 380 | W | 1,745 | -- | -- |
| Illinois | 3,419 | 14,978 | 4,273 | 18,791 | 12,405 | 43,900 | 1,867 | 7,395 |
| Indiana | 1,153 | 4,496 | 5,445 | 17,206 | 3,185 | 11,008 | 1,180 | 3,967 |
| Iowa | 1,779 | 7,423 | 2,347 | 10,390 | 5,475 | 21,190 | 236 | 1,123 |
| Kansas | 1,758 | 6,670 | 1,776 | 7,709 | 3,486 | 11,705 | 307 | 1,308 |
| Kentucky | 6,377 | 22,919 | 4,630 | 17,302 | 8,579 | 30,878 | 1,935 | 6,905 |
| Maine | W | W | W | W | W | W | W | W |
| Maryland | 2,825 | 10,740 | 2,533 | 10,254 | 5,570 | 21,518 | 288 | 1,593 |
| Massachusetts | -- | -- | (2) | W | W | W | W | W |
| Michigan | 1,680 | 4,900 | 1,549 | 5,162 | 4,191 | 11,701 | 856 | 3,072 |
| Minnesota | 270 | 901 | W | W | 2,420 | 6,520 | 142 | 489 |
| Mississippi | W | W | W | W | W | W | W | W |
| Missouri | 4,072 | 15,850 | 3,624 | 13,012 | 10,019 | 31,932 | 5,284 | 14,432 |
| Montana | -- | -- | W | W | 434 | 1,401 | -- | -- |
| Nebraska | 791 | 4,266 | 161 | 781 | 1,048 | 5,403 | 267 | 1,621 |
| Nevada | -- | -- | -- | -- | W | W | W | W |
| New Jersey | W | W | W | W | W | W | -- | -- |
| New Mexico | 343 | 897 | 187 | 696 | 581 | 2,361 | 244 | 1,451 |
| New York | 1,145 | 5,738 | 5,787 | 29,501 | 3,328 | 15,788 | 828 | 3,931 |
| North Carolina | W | W | W | W | W | W | W | W |
| Ohio | 3,375 | 11,684 | 3,750 | 15,159 | 11,911 | 41,889 | 1,391 | 4,902 |
| Oklahoma | 1,815 | 7,307 | 1,253 | 4,059 | 2,298 | 5,710 | 113 | 429 |
| Oregon | -- | -- | -- | -- | -- | -- | -- | -- |
| Pennsylvania | 4,065 | 17,379 | 6,955 | 30,337 | 11,042 | 45,621 | 532 | 2,024 |
| Rhode Island | -- | -- | -- | -- | -- | -- | -- | -- |
| South Carolina | W | W | W | W | W | W | W | W |
| South Dakota | W | W | 58 | 234 | 31 | 89 | 8 | 21 |
| Tennessee | 4,805 | 21,830 | 6,061 | 25,956 | 13,496 | 60,223 | 639 | 2,532 |
| Texas | 14,998 | 59,817 | 6,373 | 26,819 | 23,846 | 61,054 | 1,322 | 6,296 |
| Utah | -- | -- | -- | -- | 849 | 1,751 | 790 | 2,805 |
| Vermont | W | W | 411 | 1,957 | W | W | W | W |
| Virginia | 3,671 | 15,943 | 1,977 | 9,869 | 4,248 | 13,220 | 767 | 3,010 |
| Washington | -- | -- | -- | -- | W | W | 4 | 18 |
| West Virginia | 719 | 2,756 | 650 | 5,071 | 1,085 | 4,590 | 323 | 1,498 |
| Wisconsin | 812 | 2,644 | 617 | 1,748 | 5,102 | 14,662 | 241 | 986 |
| Wyoming | W | W | 66 | W | 246 | W | W | W |
| **Total (excluding withheld)[1]** | **85,011** | **381,353** | **70,456** | **297,013** | **154,114** | **528,338** | **21,470** | **79,599** |
| **Total withheld** | **2,707** | **13,714** | **1,528** | **7,798** | **3,542** | **13,399** | **2,371** | **9,906** |
| **Grand total[1]** | **87,718** | **395,068** | **71,984** | **304,813** | **157,655** | **541,739** | **23,841** | **89,505** |
| **Guam** | **231** | **1,896** | **W** | **398** | **W** | **762** | **5** | **55** |
| **Puerto Rico** | **827** | **4,876** | **38** | **213** | **8** | **42** | **15** | **23** |

W Withheld to avoid disclosing company proprietary data; included with "Total withheld" and "Other uses."

[1] Data may not add to totals shown because of independent rounding.

[2] Less than 1/2 unit.

### producers in the United States in 1985, by State and use

and thousand dollars)

| Other construction uses | | Cement manufacture | | Agricultural uses | | Lime manufacture | | Other uses | | Total[1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| 2,346 | 9,721 | 2,625 | 7,703 | 274 | 1,643 | W | W | 9,370 | 36,806 | 24,770 | 98,723 |
| -- | -- | -- | -- | -- | -- | -- | -- | W | W | W | W |
| W | W | W | W | -- | -- | W | W | 3,749 | 15,626 | 3,749 | 15,626 |
| 165 | 589 | W | W | 162 | 1,296 | W | W | 3,336 | 10,452 | 4,940 | 17,200 |
| 295 | 2,641 | 13,297 | 41,502 | 71 | 581 | 513 | 6,762 | 839 | 15,964 | 17,233 | 77,687 |
| -- | -- | W | W | -- | -- | -- | -- | 3,035 | 9,644 | 3,035 | 9,644 |
| 2 | W | 46 | 93 | 28 | W | 26 | 54 | 206 | 1,209 | 308 | 1,356 |
| 9,364 | 38,659 | 2,225 | 8,175 | 3,899 | 9,690 | -- | -- | 9,601 | 34,865 | 65,326 | 278,088 |
| 1,235 | 5,983 | W | W | 1,038 | 5,250 | -- | -- | 3,028 | 12,516 | 6,992 | 31,484 |
| W | W | W | W | 21 | 171 | -- | -- | 496 | 2,150 | 1,006 | 6,927 |
| (2) | (2) | W | W | 27 | 80 | 1 | 2 | 990 | 964 | 1,207 | 3,286 |
| 1,376 | 5,439 | 2,577 | 6,551 | 3,165 | 11,701 | W | W | 11,962 | 55,362 | 41,044 | 164,117 |
| 2,004 | 7,525 | W | W | 1,307 | 5,170 | W | 23 | 9,110 | 31,724 | 23,384 | 81,119 |
| 2,851 | 10,243 | 2,373 | 5,768 | 1,245 | 9,348 | 4 | 23 | 7,347 | 28,988 | 23,657 | 94,496 |
| 1,142 | 4,621 | 2,977 | 7,747 | 874 | 3,934 | W | W | 2,762 | 9,850 | 15,082 | 53,546 |
| 2,596 | 9,853 | W | W | 2,354 | 8,694 | W | W | 11,551 | 38,428 | 38,022 | 134,978 |
| W | W | W | W | W | W | -- | -- | 1,089 | 3,985 | 1,089 | 3,985 |
| 812 | 3,136 | 2,619 | 5,057 | W | W | 19 | 78 | 1,145 | 3,886 | 15,810 | 56,262 |
| -- | -- | -- | -- | 156 | 1,062 | W | W | W | W | W | W |
| 1,288 | 4,163 | 6,146 | 14,250 | 444 | 1,760 | 5,801 | 18,222 | 8,648 | 32,579 | 30,604 | 95,810 |
| 572 | 1,834 | -- | -- | 255 | 821 | W | W | 2,032 | 6,491 | 5,692 | 17,057 |
| W | W | W | W | 199 | 1,037 | -- | -- | 1,383 | 3,244 | 1,582 | 4,282 |
| 7,547 | 26,402 | 6,190 | 14,966 | 2,068 | 7,929 | 205 | 892 | 9,600 | 32,284 | 48,609 | 157,700 |
| -- | -- | W | W | -- | -- | -- | -- | 1,241 | 3,445 | 1,675 | 4,846 |
| 348 | 1,935 | W | W | 229 | 1,839 | -- | -- | 1,330 | 3,289 | 4,175 | 19,134 |
| -- | -- | W | W | W | W | W | W | 1,096 | 4,832 | 1,096 | 4,832 |
| W | W | -- | -- | W | W | -- | -- | W | W | W | W |
| W | W | W | W | -- | -- | -- | -- | 776 | 2,797 | 2,131 | 8,200 |
| 2,495 | 9,745 | 4,221 | 9,432 | 598 | 3,263 | W | W | 12,929 | 63,171 | 31,332 | 140,569 |
| W | W | -- | -- | 6 | 75 | -- | -- | 4,803 | 25,250 | 4,809 | 25,325 |
| 2,613 | 8,703 | 2,062 | 6,895 | 1,220 | 5,080 | 1,087 | 3,868 | 10,810 | 37,913 | 38,217 | 136,092 |
| 1,899 | 5,400 | 2,625 | 3,970 | 85 | 287 | -- | -- | 19,105 | 65,800 | 29,192 | 92,962 |
| W | W | W | W | -- | -- | -- | -- | W | W | W | W |
| 1,953 | 8,157 | 6,571 | 25,420 | 1,229 | 10,605 | 1,895 | 12,149 | 16,688 | 96,624 | 50,933 | 248,815 |
| -- | -- | -- | -- | W | 854 | -- | -- | 700 | 3,909 | 700 | 4,763 |
| W | W | -- | -- | W | W | -- | -- | 3,523 | 16,098 | 3,523 | 16,098 |
| 19 | 67 | 950 | 1,994 | -- | -- | -- | -- | 1,966 | 6,575 | 3,032 | 8,981 |
| 4,732 | 16,730 | W | W | 733 | 2,876 | -- | -- | 7,469 | 25,492 | 37,936 | 155,638 |
| 3,426 | 12,969 | 11,487 | 23,167 | 643 | 2,568 | 2,088 | 8,979 | 18,752 | 89,105 | 82,935 | 290,774 |
| (2) | (2) | 1,433 | 4,918 | W | W | W | W | 1,292 | 3,915 | 4,364 | 13,389 |
| W | W | -- | -- | -- | -- | -- | -- | 900 | 3,742 | 1,311 | 5,699 |
| 2,793 | 9,272 | 1,616 | 2,680 | 1,030 | 8,126 | W | W | 3,013 | 14,241 | 19,116 | 76,362 |
| 20 | 101 | W | W | W | W | -- | -- | 1,532 | 4,037 | 1,556 | 4,156 |
| 622 | 3,397 | 1,530 | 3,169 | 52 | 461 | W | W | 3,238 | 12,439 | 8,220 | 33,383 |
| 849 | 1,920 | W | W | 577 | 3,418 | W | W | 3,832 | 9,991 | 12,030 | 35,369 |
| W | W | 304 | 1,064 | -- | -- | -- | -- | 1,027 | 4,999 | 1,643 | 6,063 |
| 55,364 | 209,205 | 73,874 | 194,521 | 23,989 | 109,619 | 11,639 | 51,052 | 217,304 | 884,681 | 713,067 | 2,734,323 |
| 4,568 | 25,594 | 18,123 | 53,690 | 529 | 3,132 | 6,557 | 22,307 | 3,128 | 16,507 | 3,284 | 17,569 |
| 59,932 | 234,798 | 91,998 | 248,213 | 24,517 | 112,750 | 18,195 | 73,359 | XX | XX | 716,400 | 2,751,900 |
| 147 | 621 | -- | -- | -- | -- | -- | -- | 165 | -- | 548 | 3,731 |
| -- | -- | 1,124 | 5,089 | -- | -- | -- | -- | 1,380 | 6,508 | 3,392 | 16,751 |

XX Not applicable.

### Table 13.—Crushed limestone and dolomite sold or used by producers in the United States in 1985, by use

(Thousand short tons and thousand dollars)

| Use | Limestone |  | Dolomite |  |
|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value |
| Coarse aggregate (+1-1/2 inch): |  |  |  |  |
| Macadam | 11,910 | 43,974 | 206 | 700 |
| Riprap and jetty stone | 13,862 | 51,263 | 538 | 1,848 |
| Filter stone | 4,677 | 19,262 | 93 | 273 |
| Other coarse aggregate | 628 | 2,902 | W | 1 |
| Coarse aggregate, graded: |  |  |  |  |
| Concrete aggregate, coarse | 68,571 | 312,520 | 2,284 | 8,537 |
| Bituminous aggregate, coarse | 42,274 | 177,932 | 2,552 | 10,620 |
| Bituminous surface treatment aggregate | 15,321 | 67,989 | 919 | 4,959 |
| Railroad ballast | 7,544 | 28,764 | 1,896 | 7,630 |
| Other graded coarse aggregate | 667 | 2,427 | -- | -- |
| Fine aggregate (-3/8 inch): |  |  |  |  |
| Stone sand, concrete | 12,663 | 58,514 | 613 | 3,015 |
| Stone sand, bituminous mix or seal | 8,431 | 32,210 | 1,026 | 3,675 |
| Screening, undesignated | 10,028 | 38,737 | 426 | 1,618 |
| Other fine aggregate | 3,560 | 12,389 | W | W |
| Coarse and fine aggregate: |  |  |  |  |
| Graded road base or subbase | 110,918 | 369,794 | 3,400 | 12,466 |
| Unpaved road surfacing | 30,093 | 110,284 | 498 | 1,617 |
| Terrazzo and exposed aggregate | 676 | 4,167 | 36 | 197 |
| Crusher run or fill or waste | 36,768 | 139,492 | 1,214 | 4,310 |
| Other coarse and fine aggregate | 942 | 3,549 | -- | -- |
| Other construction materials | 8,594 | 30,007 | 666 | 2,194 |
| Agricultural: |  |  |  |  |
| Agricultural limestone | 20,637 | 86,925 | 1,455 | 7,936 |
| Poultry grit and mineral food | 1,875 | 15,351 | W | W |
| Other agricultural uses | 422 | 2,024 | W | W |
| Chemical and metallurgical: |  |  |  |  |
| Cement manufacture | 91,930 | 247,826 | W | W |
| Lime manufacture | 16,657 | 64,732 | 520 | 1,921 |
| Dead-burned dolomite manufacture | 433 | 4,467 | W | W |
| Flux stone | 7,560 | 31,435 | 2,717 | 10,049 |
| Chemical stone | 558 | 2,383 | W | W |
| Glass manufacture | 404 | 3,500 | -- | -- |
| Sulfur oxide removal | 1,427 | 5,527 | 32 | W |
| Special: |  |  |  |  |
| Mine dusting or acid water treatment | 651 | 4,057 | -- | -- |
| Asphalt fillers or extenders | 785 | 4,977 | W | 25 |
| Whiting or whiting substitute | 672 | 12,687 | W | 100 |
| Other fillers or extenders | 2,978 | 38,173 | 373 | 4,314 |
| Abrasives | 302 | 1,277 | -- | -- |
| Lightweight aggregate | 181 | 1,319 | -- | -- |
| Roofing granules | 1,993 | 12,595 | 2 | 5 |
| Paper manufacture | 640 | 1,779 | -- | -- |
| Other miscellaneous uses | 8,480 | 43,985 | 1,422 | 6,134 |
| Other unspecified uses[1] | 138,289 | 527,426 | 8,460 | 39,132 |
| **Total[2]** | **685,000** | **2,618,600** | **31,350** | **133,300** |

W Withheld to avoid disclosing company proprietary data; included with "Special: Other miscellaneous uses."

[1] Includes production without a breakdown by use and estimates for nonrespondents.

[2] Data may not add to totals shown because of independent rounding.

## Table 14.—Crushed marble sold or used by producers in the United States in 1985, by use

(Thousand short tons and thousand dollars)

| Use | Quantity | Value |
|---|---|---|
| Other agricultural uses | W | 215 |
| Stone sand, concrete | W | W |
| Terazzo and exposed aggregate | 44 | 382 |
| Other construction and maintenance uses[1] | 454 | 2,376 |
| Whiting or whiting substitute and fillers | 1,276 | 10,741 |
| Other[2] | 103 | 3,120 |
| Other miscellaneous uses | 560 | 3,604 |
| Total | 2,437 | [3]20,440 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes concrete aggregate (coarse), graded road base or subbase, bituminous surface treatment aggregate, unpaved road surfacing, riprap and jetty stone, railroad ballast, and crusher run (select material or fill).

[2] Includes poultry grit and mineral food, stone sand, and fillers and extenders.

[3] Data do not add to total shown because of independent rounding.

## Table 15.—Crushed granite and traprock sold or used by producers in the United States in 1985, by use

(Thousand short tons and thousand dollars)

| Use | Granite | | Traprock | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Coarse aggregate (+1-1/2 inch): | | | | |
| Macadam | 580 | 2,833 | 1,989 | 9,150 |
| Riprap and jetty stone | 3,255 | 18,091 | 2,555 | 11,240 |
| Filter stone | 681 | 3,419 | 636 | 2,790 |
| Other coarse aggregate | 79 | 288 | 257 | 1,477 |
| Coarse aggregate, graded: | | | | |
| Concrete aggregate, coarse | 24,260 | 125,242 | 8,785 | 48,008 |
| Bituminous aggregate, coarse | 10,490 | 53,564 | 6,710 | 36,849 |
| Bituminous surface treatment aggregate | 5,818 | 30,448 | 2,108 | 9,750 |
| Railroad ballast | 10,637 | 41,107 | 2,422 | 9,876 |
| Other graded coarse aggregate | W | W | W | W |
| Fine aggregate (-3/8 inch): | | | | |
| Stone sand, concrete | 6,158 | 32,565 | 1,679 | 12,033 |
| Stone sand, bituminous mix or seal | 2,228 | 9,936 | 1,472 | 6,816 |
| Screening, undesignated | 7,727 | 33,226 | 1,179 | 5,954 |
| Coarse and fine aggregate: | | | | |
| Graded road base or subbase | 25,635 | 110,238 | 21,616 | 91,322 |
| Unpaved road surfacing | 2,038 | 8,965 | 4,749 | 16,761 |
| Terrazzo and exposed aggregate | 303 | 1,653 | 2,088 | 14,455 |
| Crusher run or fill or waste | 24,046 | 109,520 | 2,422 | 7,942 |
| Other coarse and fine aggregate | -- | -- | W | W |
| Other construction materials | 6,711 | 30,205 | 1,374 | 6,975 |
| Agricultural: | | | | |
| Agricultural limestone | W | W | W | W |
| Poultry grit and mineral food | W | W | -- | -- |
| Chemical and metallurgical: | | | | |
| Cement manufacture | W | W | -- | -- |
| Lime manufacture | W | W | -- | -- |
| Chemical stone | -- | -- | W | W |
| Special: | | | | |
| Asphalt fillers or extenders | 17 | 290 | -- | -- |
| Whiting or whiting substitute | -- | -- | 45 | 116 |
| Abrasives | W | W | -- | -- |
| Roofing granules | W | W | W | W |
| Sugar refining | -- | -- | W | W |
| Other miscellaneous uses | 1,240 | 4,959 | 1,456 | 5,830 |
| Other unspecified uses[1] | 13,350 | 53,255 | 19,998 | 90,681 |
| Total[2] | 145,300 | 669,800 | 83,550 | 388,000 |

W Withheld to avoid disclosing company proprietary data; included with "Special: Other miscellaneous uses."

[1] Includes production reported without a breakdown by end use, and estimates for nonrespondents.

[2] Data may not add to totals shown because of independent rounding.

## Table 16.—Crushed sandstone and quartzite sold or used by producers in the United States in 1985, by use

(Thousand short tons and thousand dollars)

| Use | Sandstone | | Quartzite | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Coarse aggregate (+1-1/2 inch): | | | | |
| Macadam | W | W | -- | -- |
| Riprap and jetty stone | 899 | 4,087 | 34 | 140 |
| Filter stone | 85 | 482 | W | W |
| Other coarse aggregate | W | W | -- | -- |
| Coarse aggregate, graded: | | | | |
| Concrete aggregate, coarse | 1,163 | 6,149 | 594 | 3,391 |
| Bituminous aggregate, coarse | 1,106 | 5,855 | 117 | 597 |
| Bituminous surface treatment aggregate | 684 | 4,595 | 130 | 763 |
| Railroad ballast | 317 | 2,010 | W | W |
| Other graded coarse aggregate | W | W | -- | -- |
| Fine aggregate (-3/8 inch): | | | | |
| Stone sand, concrete | 355 | 1,883 | W | W |
| Stone sand, bituminous mix or seal | 386 | 1,683 | W | W |
| Screening, undesignated | 364 | 1,391 | W | W |
| Other fine aggregate | W | W | -- | -- |
| Coarse and fine aggregate: | | | | |
| Graded road base or subbase | 4,637 | 19,074 | 1,027 | 4,247 |
| Unpaved road surfacing | 217 | 933 | W | W |
| Terrazzo and exposed aggregate | 29 | 435 | -- | -- |
| Crusher run or fill or waste | 765 | 2,588 | W | W |
| Other coarse and fine aggregate | W | W | -- | -- |
| Other construction materials | 1,203 | 4,479 | 617 | 3,753 |
| Agricultural: | | | | |
| Poultry grit and mineral food | -- | -- | W | W |
| Chemical and metallurgical: | | | | |
| Cement manufacture | 244 | 580 | 118 | 385 |
| Flux stone | W | W | W | W |
| Special: | | | | |
| Whiting or whiting substitute | -- | -- | 121 | W |
| Lightweight aggregate | ([1]) | 10 | -- | -- |
| Other miscellaneous uses | 7,345 | 30,295 | 592 | 3,677 |
| Other unspecified uses[2] | W | W | -- | -- |
| Total[3] | 19,800 | 86,530 | 3,348 | 16,950 |

W Withheld to avoid disclosing company proprietary data; included with "Special: Other miscellaneous uses."

[1] Less than 1/2 unit.

[2] Includes production reported without a breakdown by end use, and estimates for nonrespondents.

[3] Data may not add to totals shown because of independent rounding.

### Table 17.—Crushed volcanic cinder and scoria sold or used by producers in the United States in 1985, by use

(Thousand short tons and thousand dollars)

| Use | Quantity | Value |
|---|---|---|
| Coarse aggregate (+1-1/2 inch): | | |
| Riprap and jetty stone | 9 | 49 |
| Filter stone | W | W |
| Other coarse aggregate | 63 | 65 |
| Concrete aggregate, graded: | | |
| Concrete aggregate, coarse | 49 | 152 |
| Bituminous surface treatment aggregate | 32 | 168 |
| Railroad ballast | W | W |
| Fine aggregate (-3/8 inch): | | |
| Stone sand, concrete | 4 | W |
| Stone sand, bituminous mix or seal | W | W |
| Screening, undesignated | W | W |
| Coarse and fine aggregate: | | |
| Graded road base or subbase | 462 | 2,283 |
| Unpaved road surfacing | 585 | 1,612 |
| Terrazzo and exposed aggregate | 94 | 1,314 |
| Crusher run or fill or waste | 58 | W |
| Other coarse and fine aggregate | 3 | 6 |
| Other construction materials[1] | 350 | 2,125 |
| Special: | | |
| Other fillers or extenders | W | W |
| Lightweight aggregate | 452 | 1,607 |
| Roofing granules | 17 | 66 |
| Paper manufacture | W | W |
| Other miscellaneous uses[2] | 260 | 1,443 |
| Other unspecified uses[3] | 513 | 1,613 |
| Total[4] | 2,953 | 12,500 |

W Withheld to avoid disclosing company proprietary data; included with "Other miscellaneous uses."

[1] Includes railroad ballast, filler stone, other fillers or extenders, stone sand (bituminous mix or seal), and fine aggregate screen.

[2] Includes paper manufacture, waste material, and miscellaneous uses.

[3] Includes production reported without a breakdown by use and estimates for nonrespondents.

[4] Data may not add to totals shown because of independent rounding.

### Table 18.—Crushed miscellaneous stone[1] sold or used by producers in the United States in 1985, by use

(Thousand short tons and thousand dollars)

| Use | Quantity | Value |
|---|---|---|
| Coarse aggregate (+1-1/2 inch): | | |
| Macadam | W | W |
| Riprap and jetty stone | 288 | 2,534 |
| Other coarse aggregate | ([2]) | 2 |
| Coarse aggregate, graded: | | |
| Concrete aggregate, coarse | 555 | 2,303 |
| Bituminous aggregate, coarse | W | W |
| Bituminous surface treatment aggregate | W | W |
| Railroad ballast | 83 | 239 |
| Fine aggregate (-3/8 inch): | | |
| Stone sand, concrete | W | W |
| Stone sand, bituminous mix or seal | 44 | W |
| Screening, undesignated | ([2]) | 2 |
| Coarse and fine aggregate: | | |
| Graded road base or subbase | 8,111 | 37,179 |
| Unpaved road surfacing | 3,329 | 17,413 |
| Terrazzo and exposed aggregate | 10 | 72 |
| Crusher run or fill or waste | 1,887 | 6,991 |
| Other construction materials | 643 | 2,675 |
| Poultry grit and mineral food | 82 | 6,207 |
| Other agricultural uses | W | W |
| Chemical and metallurgical: | | |
| Cement manufacture | 3,922 | 8,015 |
| Chemical stone | W | W |
| Other miscellaneous uses[3] | 3,126 | 7,447 |
| Other unspecified uses[4] | 5,027 | 15,662 |
| Total[5] | 27,100 | 106,700 |

W Withheld to avoid disclosing company proprietary data; included with "Other miscellaneous uses."

[1] Includes marl, other stone, shell, and slate.

[2] Less than 1/2 unit.

[3] Includes abrasives, lime manufacture, mine dusting, roofing granules, and sugar refining.

[4] Includes production reported without a breakdown by end use, and estimates for nonrespondents.

[5] Data may not add to totals shown because of independent rounding.

## PRICES

Compared with 1983, the 1985 average unit price of crushed stone increased 5% to $4.05. By kind of stone, the average unit prices showed increases of 1% for dolomite, 3% for limestone, 4% for shell, 8% for sandstone and quartzite, 10% for granite, and 12% for traprock, and decreases of 11% for calcareous marl and 15% for volcanic cinder and scoria. Some very large decreases, mostly owing to changes in end uses, occurred for marble (-52%) and slate (-55%).

## TRANSPORTATION

Of the total crushed stone produced, 85% was transported by truck from the plant or quarry to the site of the first point of sale or use, 5% was transported by rail, and 4% by waterway. Information regarding the distance to which crushed stone was shipped or cost per ton per mile was not available.

### Table 19.—Crushed stone sold or used by producers in the United States in 1985, by method of transportation

| Method of transportation | Quantity (thousand short tons) | Percent |
|---|---|---|
| Truck | 850,109 | 85 |
| Rail | 48,830 | 5 |
| Water | 39,536 | 4 |
| Other | 62,321 | 6 |
| Total | [1]1,000,800 | 100 |

[1] Data do not add to total shown because of independent rounding.

## FOREIGN TRADE

**Exports.**—Exports of crushed stone were unchanged from the 1984 level and totaled 2.4 million tons, while the value increased 22% to $29 million. Exports of limestone accounted for 95% of the 2.4 million tons, an increase of 4% over that of 1984. Ninety-eight percent of this total was exported to Canada.

**Imports.**—Imports of crushed stone decreased 7% in volume to 2.7 million tons and 32% in value to $10.2 million. About 48% of this tonnage was limestone, 64% of which came from Canada.

Imports of calcium carbonate fines decreased 4% in volume to 281,000 tons and 42% in value to $1.4 million. Of the natural calcium carbonate (aragonite), over 99% came from the Bahamas, while most of the processed calcium carbonate was imported, in decreasing order of tonnage, from France, the United Kingdom, and the Federal Republic of Germany. Precipitated calcium carbonate is covered in the "Calcium and Calcium Compounds" chapter.

### Table 20.—U.S. exports of crushed stone in 1985, by destination

(Thousand short tons unless otherwise specified)

| Destination | Quartzite | Limestone[1] | Other | Total[2] |
|---|---|---|---|---|
| North America: | | | | |
| Canada | 1 | 2,222 | 71 | 2,293 |
| Mexico | ([3]) | ([3]) | 11 | 11 |
| Total | 1 | 2,222 | 82 | 2,304 |
| South America: | | | | |
| Bolivia | -- | 18 | -- | 18 |
| Venezuela | -- | 18 | 1 | 19 |
| Other | ([3]) | 6 | 3 | 9 |
| Total[2] | ([3]) | 42 | 4 | 45 |
| Europe: | | | | |
| France | 1 | -- | 3 | 4 |
| Germany, Federal Republic of | 3 | ([3]) | ([3]) | 3 |
| Netherlands | 1 | -- | -- | 1 |
| United Kingdom | 1 | -- | 3 | 4 |
| Other | 1 | -- | 1 | 1 |
| Total[2] | 6 | ([3]) | 7 | 13 |
| Asia: | | | | |
| Japan | 1 | ([3]) | 1 | 3 |
| Other | 1 | ([3]) | ([3]) | 1 |
| Total[2] | 2 | ([3]) | 2 | 4 |
| Oceania | -- | 1 | 4 | 4 |
| Middle East and Africa | ([3]) | ([3]) | ([3]) | 1 |
| Grand total[2] | 9 | 2,265 | 98 | 2,372 |
| Total value thousands | $10,645 | $15,107 | $3,594 | $29,347 |

[1] Includes ground limestone.
[2] Data may not add to totals shown because of independent rounding.
[3] Less than 1/2 unit.

Source: Bureau of the Census.

**Table 21.—U.S. imports for consumption of crushed stone and calcium carbonate fines, by type**

(Thousand short tons and thousand dollars)

| Type | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Customs value | Quantity | Customs value |
| Crushed stone and chips: | | | | |
| Limestone | 1,645 | 10,646 | 1,299 | 5,261 |
| Marble, breccia | 2 | 181 | 29 | 547 |
| Quartzite | 64 | 945 | 33 | 638 |
| Slate | 10 | 47 | 2 | 99 |
| Other | 1,202 | 3,251 | 1,361 | 3,664 |
| Total[1] | 2,923 | 15,071 | 2,725 | 10,209 |
| Calcium carbonate fines:[2] | | | | |
| Natural aragonite[3] | 275 | 710 | 274 | 716 |
| Chalk, whiting | 17 | 1,761 | 7 | 715 |
| Total[1] | 292 | 2,471 | 281 | 1,432 |
| Grand total[1] | 3,215 | 17,543 | 3,006 | 11,640 |

[1] Data may not add to totals shown because of independent rounding.
[2] Excludes precipitated calcium carbonate.
[3] Includes some chalk and other calcareous materials.

Source: Bureau of the Census.

## WORLD REVIEW

**Australia.**—The government of Western Australia introduced a computerized information system that will allow instant access to the results of previous mineral explorations performed by mining companies. Under the provisions of the Mining Act, companies are required to report all technical details of their exploration activities to the Department of Mines. These reports become eligible for open-file release when the exploration tenements are relinquished. Companies interested in new explorations will be able to review previous exploration programs and, therefore, avoid costly duplications by having access to such reports.[2]

**Canada.**—The 1984 production of stone in Canada was 81.8 million tons valued at $393 million; about 95% of this output was crushed stone. The Province of Ontario continued to be the largest producer of stone with 34 million tons valued at $160 million, followed by Quebec with 31 million tons valued at $139 million. Preliminary estimates for 1985 stone production indicate a decrease of 5% to 78 million tons valued at $378 million, with the Province of Ontario accounting for about 40% of the total output.

## TECHNOLOGY

Effective January 1, 1985, the National Crushed Stone Association and the National Limestone Institute were consolidated into one organization called the National Stone Association. This new trade organization became the sole representative of the entire crushed stone industry. The first annual convention of the new association was held in Bal Harbour, FL, on January 20-23, 1985, and was attended by over 700 members and prospective members. The goal of the new association, the economic outlook, and the legislative matters that may impact the crushed stone industry were the major topics discussed.[3]

Beginning with the 1985 biennial survey, the Bureau of Mines implemented new reporting procedures for crushed stone production at the State level. Most of the States were subdivided into Bureau districts by grouping several adjacent counties. Consequently, the number of companies within each district increased significantly, making more information available for publication. The new tables showing production of crushed stone within each district are published in the Bureau of Mines "Minerals Yearbook, Volume II, Area Reports: Domestic."[4]

The potential demand in the 1990's for limestone and lime used for sulfur removal was analyzed by the Illinois Department of

Energy and Natural Resources in a study based on the projections for sulfur control prepared by the North American Electric Reliability Council. Two models were considered in these projections. One was based on the provisions of the present Clean Air Act regulations, and the second was based on the requirements of the proposed acid rain legislation. The study concludes that, in 1992, the demand for limestone used for sulfur removal is expected to be between 7.9 and 9.9 million tons under the first scenario, and an additional 21.3 to 26.6 million tons of limestone under the assumptions made for the second.[5]

An extensive review of limestone specifications from construction aggregates and road materials to cement manufacturing, agricultural uses, glass manufacturing, and use as fillers and extenders, was published. The specifications were derived from the British Standards Institute and other British Government and corporate guidelines. Although the published specifications are related to British manufacturing practice, they provide a general guide to the typical properties required for limestone used in a variety of applications.[6]

The recent advances achieved in high intensity wet- and dry-magnetic separation techniques extended their usefulness for processing of industrial minerals. New developments included the use of strong rare-earth permanent magnetic separators, large particle size electromagnetic separators, and superconducting cryogenic wet and dry systems. Several systems capable of separating minerals on the basis of their magnetic repelling properties rather than their attracting properties are also being studied.[7]

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[1] Physical scientist, Division of Industrial Minerals.

[2] Clark, G. Mines Department Launches First Computerized Database. Ind. Miner. (London), No. 214, July 1985, p. 9.

[3] Huhta, R. S. Stone Producers "On Their Way." Rock Prod., v. 88, No. 3, Mar. 1985, pp. 41-46.

[4] Tepordei, V. V. Bureau of Mines Revises System. Rock Prod., v. 88, No. 12, Dec. 1985, pp. 56-57, 84.

[5] Bhagwat, S. B. The Lime and Limestone Market for Sulfur Removal: Potential for 1992. IL State Geol. Surv.—IL Miner. Note 90, 1985, p. 13.

[6] Power, T. Limestone Specifications—Limiting Constraints on the Market. Ind. Miner. (London), No. 217, Oct. 1985, pp. 65-91.

[7] Clark, G. Magnetic Separation. Ind. Miner. (London), No. 212, May 1985, pp. 21-23.

# Dimension Stone

### By Harold A. Taylor, Jr.[1]

Production of dimension stone decreased 3%, to 1.12 million short tons valued at $172 million, after showing little change over the previous 7 years. Approximately one-half of the dimension stone produced was granite. Limestone, sandstone, slate, and marble were also produced.

Exports of dimension stone decreased 40% in value to $14 million. The value of dimension stone imports increased 32% to $295 million, equivalent to 172% of the value of domestic production.

**Domestic Data Coverage.**—Domestic production data for dimension stone are developed by the Bureau of Mines from voluntary surveys of U.S. producers of rough and finished dimension stone. Of the 408 dimension stone operations surveyed, including those that were idle, 341, or 82%, responded, representing 95% of the total value shown in table 1. Production data for nonrespondents were estimated using preliminary production reports, adjusted prior years production levels, and employment data.

**Table 1.—Salient U.S. dimension stone statistics**

(Thousand short tons and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Sold or used by producers[1] | 1,331 | [e]1,089 | 1,090 | [e]1,157 | 1,121 |
| Value[1] | $150,463 | [e]$137,671 | $147,843 | [e]$154,949 | $171,667 |
| Exports (value) | $20,698 | $18,678 | [r]$19,126 | [r]$23,007 | $13,835 |
| Imports for consumption (value) | $182,904 | $169,874 | [r]$191,362 | [r]$223,150 | $295,094 |

[e]Estimated. [r]Revised.
[1]Does not include Puerto Rico.

## DOMESTIC PRODUCTION

Dimension stone was produced by 196 companies at 275 quarries in 36 States. Leading States, in order of tonnage, were Indiana, Georgia, and Vermont, producing, together, 44% of the Nation's total. Notable was an 8% decrease in Georgia and an 18% increase in Indiana. Of the total production, 54% was granite, 27% was limestone, 11% was sandstone, 4% was slate, 3% was marble, and the remaining 1% was miscellaneous stone, including argillite, schist, soapstone, and traprock (basalt). Leading producing companies in terms of tonnage were Rock of Ages Corp., in Vermont and New Hampshire, and Cold Spring Granite Co., principally in California, Minnesota, South Dakota, and Texas.

**Granite.**—Dimension granite includes all coarse-grained igneous rocks. Production decreased 6% to 602,000 tons and decreased slightly in value to $93.9 million. Dimension granite was produced by 74 companies at 115 quarries in 20 States. Georgia continued to be the leading State producing 27% of the U.S. total, followed by Vermont and New Hampshire. These three States together produced over one-half of the U.S. total. Of significance was a production decrease of 10% in Georgia, while New Hampshire registered a 34% production increase. Leading producing companies were Rock of Ages, Cold Spring Granite, and H. E. Fletcher

Co. It was estimated that the three leading companies produced about one-third of U.S. output.

Keystone Memorials Inc. built a new saw building and installed a new West German automatic computerized diamond block saw at its Missouri Red granite quarry at Graniteville, MO.

New England Stone Industries Inc. of Providence, RI, bought the old Crotch Island, ME, granite quarry and its adjacent finishing facility in October and employed seven men to begin quarrying the granite. The firm planned to employ 40 to 50 people within the next few years.

**Limestone.**—Dimension limestone includes bituminous, dolomitic, and siliceous limestones. It was produced by 40 companies at 51 quarries in 16 States. Indiana continued to be the leading State, followed by Wisconsin. The top three producers, in order of value, were Indiana Limestone Co. Inc., Vetter Stone Co., and Elliott Stone Co. Inc., in Indiana, Minnesota, and Indiana, respectively.

**Marble.**—Dimension marble includes certain hard limestones, travertines, and any other calcareous stone that can be polished. Dimension marble was produced by 9 companies at 13 quarries in 9 States. Georgia, Vermont, and Montana, in order of tonnage, were the three leading States, accounting for approximately 72% of U.S. output. Leading producers were Georgia Marble Co., Vermont Marble Co., and Moretti-Harrah Marble Co. The top three companies accounted for 93% of U.S. output.

Rocky Mountain Stone Co., a travertine producer in New Mexico, has equipped its plant with new Italian state-of-the-art stone finishing machinery valued at $500,000. The plant was designed to cut and polish 2,000 square feet of stone per day. Part of the capital required was obtained through a State development loan fund.

**Sandstone.**—Dimension sandstone includes calcareous- and siliceous-cemented sandstones or conglomerates. Quartzite, which is also included, may be described as any siliceous-cemented sandstone. It was produced by 47 companies at 59 quarries in 18 States. Leading States continued to be, in order of volume, Ohio, Pennsylvania, and Georgia; these three States accounted for almost two-thirds of U.S. output. Standard Slag Co. in Ohio, Delaware Quarries Inc. in Pennsylvania, and Waller Bros. Stone Co. in

**Table 2.—Dimension stone sold or used by producers in the United States, by State**

| State | 1984[e] |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Alabama | 7,585 | $2,674 | 10,629 | $2,881 |
| Arizona | 20 | (1) | (1) | (1) |
| Arkansas | -- | -- | 5,145 | 305 |
| California | 22,240 | 2,990 | 23,181 | 2,449 |
| Colorado | 999 | 87 | 2,350 | 204 |
| Connecticut | 17,578 | 1,080 | 19,715 | 1,285 |
| Georgia | 202,030 | 20,007 | 185,202 | 19,466 |
| Illinois | -- | -- | 1,750 | 107 |
| Indiana | 159,126 | 14,269 | 188,245 | 20,186 |
| Maryland | 16,698 | 864 | 17,833 | 1,218 |
| Massachusetts | 56,982 | 11,657 | 72,577 | 13,724 |
| Michigan | 4,225 | 129 | 4,162 | 113 |
| Minnesota | 38,746 | 13,369 | 36,808 | 13,598 |
| New Hampshire | 58,740 | 4,198 | 78,642 | 6,532 |
| New Mexico | 19,257 | 149 | 20,495 | 277 |
| New York | 14,859 | 4,271 | 16,032 | 3,666 |
| North Carolina | W | W | 35,333 | 6,132 |
| Ohio | 36,853 | 3,454 | 53,067 | 3,661 |
| Oklahoma | 12,074 | 771 | 10,862 | 836 |
| Pennsylvania | 44,376 | 6,001 | 51,268 | 8,214 |
| South Carolina | 16,130 | 1,092 | 7,756 | 541 |
| South Dakota | 59,597 | 18,642 | W | W |
| Tennessee | 7,021 | 1,097 | 4,793 | 773 |
| Texas | 46,937 | 11,236 | 37,262 | 11,760 |
| Vermont | 116,005 | 20,462 | 116,166 | 26,346 |
| Virginia | 22,063 | 3,052 | 9,653 | 3,136 |
| Washington | -- | -- | 761 | 53 |
| Wisconsin | 24,028 | 2,863 | 21,920 | 2,733 |
| Other[2] | 152,458 | 10,534 | 88,929 | 21,471 |
| Total[3] | 1,156,622 | 154,949 | 1,120,585 | 171,667 |

[e] Estimated. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Less than 1/2 unit.

[2] Includes Idaho, Iowa, Kansas, Maine, Missouri, Montana, Oregon, Utah, and data indicated by symbol W.

[3] Data may not add to totals shown because of independent rounding.

Ohio were the leading producers and accounted for 36% of U.S. production.

**Slate.**—Dimension slate was produced by 19 companies at 28 quarries in 6 States. The two leading States in order of volume, Pennsylvania and Vermont, accounted for 70% of U.S. output. The top three producers, A. Dally and Sons Inc., Vermont Structural Slate Co. Inc., and Le Sueur-Richmond Slate Co. Inc., accounted for an estimated 45% of U.S. output by value. Hilltop Slate Co., a slate producer in New York and Vermont, was bought by the Penrhyn Quarries Ltd., a subsidiary of the Alfred McAlpine PLC of the United Kingdom.

**Miscellaneous Stone.**—Miscellaneous dimension stone, including traprock, was produced by seven companies from seven quarries in six States, and totaled 15,288 tons valued at $956,488.

### Table 3.—Dimension granite sold or used by producers in the United States, by State

| State | 1984[e] | | 1985[p] | | |
|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Cubic feet (thousands) | Value (thousands) |
| Connecticut | W | W | 11,310 | 136 | $919 |
| Georgia | 179,000 | $9,500 | 160,377 | 1,606 | 9,133 |
| Massachusetts | 55,000 | W | W | W | W |
| New Hampshire | 58,700 | 4,200 | 78,642 | 953 | 6,532 |
| Oklahoma | W | W | 6,112 | 74 | 734 |
| South Carolina | 16,100 | 1,100 | 7,756 | 97 | 541 |
| South Dakota | 59,600 | 18,600 | W | W | W |
| Texas | 87,000 | 11,000 | W | W | W |
| Wisconsin | W | W | 8,133 | 87 | 1,891 |
| Other[1] | 232,600 | 50,600 | 334,903 | 4,071 | 74,134 |
| Total | 638,000 | 95,000 | 602,233 | 6,974 | 93,884 |

[e]Estimated. [p]Preliminary. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes California, Colorado, Maine, Maryland, Minnesota, Missouri, New York, North Carolina, Pennsylvania, Vermont, Virginia (1984), Washington (1985), and data indicated by symbol W.

### Table 4.—Dimension limestone sold or used by producers in the United States in 1985, by State

| Use | Quantity (short tons) | Cubic feet (thousands) | Value (thousands) |
|---|---|---|---|
| California | 3,331 | 42 | $116 |
| Illinois | 1,750 | 21 | 107 |
| Indiana | W | W | W |
| Virginia | 611 | 7 | 33 |
| Wisconsin | 18,787 | 235 | 842 |
| Other[1] | 277,795 | 3,728 | 33,797 |
| Total | 302,274 | 4,033 | 34,895 |

[1] Includes Alabama, Iowa, Kansas, Maryland, Michigan, Minnesota, New Mexico, Ohio, Oklahoma, Texas, Washington, and data indicated by symbol W.

### Table 5.—Dimension sandstone sold or used by producers in the United States in 1985, by State

| State | Quantity (short tons) | Cubic feet (thousands) | Value (thousands) |
|---|---|---|---|
| Arkansas | 5,145 | 64 | $305 |
| Connecticut | 8,405 | 108 | 366 |
| Maryland | 6,055 | 76 | 502 |
| Missouri | 230 | 3 | 18 |
| New York | 7,788 | 99 | 491 |
| Pennsylvania | 23,803 | 305 | 1,019 |
| Other[1] | 74,490 | 995 | 4,909 |
| Total | 125,916 | [2]1,652 | 7,610 |

[1] Includes Alabama, Arizona, California, Colorado, Georgia, Idaho, Michigan, North Carolina, Ohio, Oklahoma, Tennessee, and Utah.

[2] Data do not add to total shown because of independent rounding.

Table 6.—Dimension marble sold or used by producers in the United States in 1985, by State

| State | Quantity (short tons) | Cubic feet (thousands) | Value (thousands) |
|---|---|---|---|
| Idaho | 845 | W | W |
| Other[1] | 33,315 | 387 | $20,658 |
| Total | 34,160 | 387 | 20,658 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes Alabama, Georgia, Massachusetts, Montana, New Mexico, North Carolina, Tennessee, Vermont, and data indicated by symbol W.

## CONSUMPTION AND USES

Dimension stone was marketed over wide areas. Industry stockpiles were not monitored, and production during 1985 was assumed to equal consumption.

Consumption of domestic dimension stone decreased slightly to 1.12 million tons valued at $171.7 million. Dressed slabs and blocks for building construction were 19% of the total value of consumption, followed by ashlars and partially squared, dressed pieces, 19%; dressed monumental stone, 15%; and rough stone used for monumental purposes, 14%; and rough blocks used for building and construction, 10%.

Of the total consumption of domestic granite, 24% by value was rough monumental stone, 23% was other dressed stone, and 22% was dressed monumental granite.

Consumption of domestic limestone totaled 302,300 tons valued at $34.9 million, of which 76% by value was dressed stone for building, and 21% was other rough stone.

Several manufacturing facilities to make resin agglomerated stone, a marble and granite look-alike, recently came on-stream. Armstar's Breton-equipped plant at Lenoir City, TN, produced a 3/8-inch and 3/16-inch-thick marblelike tile out of a mixture of marble chips and resin. The color of the tile was a reflection of the natural colors of the chips used to make it. Marmor Works Ltd. began making celtic granite slabs for cladding and flooring at its new plant in Wales from silica-rich aggregate and pigmented polyester resin binders. The product was said to be 90% cheaper than natural stone cladding to match the performance characteristics of granite for fire, weathering, and abrasion resistance, and to exceed these characteristics for marble.

The appearance of several artificial slate roofing materials accompanied the strong British market for natural slate roofing in the last several years. Redland Roof Tiles Ltd. began production of its new lightweight interlocking roofing slatelike product, which it will market first in southwest England. The product, called Cambrian, was mostly made from crushed and ground natural slate and stone (65%) combined with glass fiber and a resin binder and individually molded to give a single reinforced tile with an interlocking fixing mechanism. The tile surface was made to resemble that of natural slate and undergoes a preweathering process to make it look even more natural. The interlocking feature allows the tile to be laid single lap, thus lessening substantially the amount of material required to cover the roof, compared with natural slate, which must be double lapped on the roof. The interlocking feature also minimized the nailing required and therefore lengthens the time until corroding nails make roof repair or replacement necessary.[2]

Anglia Resins Ltd. began selling its Anglia Slate on the British roofing market. The product was made from a blend of fine-grained silica, colorfast pigment and a methacrylate resin binder. Anglia Slate can convincingly substitute for any natural slate because the pigments can be mixed to match any color, and the product varies from piece to piece as the natural slate would because it is made in different molds that give different surface textures. The firm invented the process and designed its own production machinery. The product usually was priced under British natural roofing slate but above Spanish imported slate. Anglia Slate is easy to install because it is predrilled, lighter, and more consistent in size than natural slate. Both of these manufactured slatelike roofing products provided formidable competition to roofing slate.

## Table 7.—Dimension stone sold or used by producers in the United States in 1985, by use

| Use | Quantity (short tons) | Cubic feet (thousands) | Value (thousands) |
|---|---|---|---|
| Rough stone: | | | |
| Rough blocks for building and construction | 267,866 | 3,445 | $17,189 |
| Irregular-shaped stone[1] | 152,182 | 1,864 | 6,005 |
| Monumental | 232,129 | 2,566 | 23,240 |
| Flagging | 923 | 12 | 61 |
| Other[2] | 6,968 | 83 | 283 |
| Dressed stone: | | | |
| Ashlars and partially squared pieces | 138,405 | 1,765 | 32,967 |
| Slabs and blocks for building and construction[3] | 102,669 | 1,303 | 33,195 |
| Monumental | 58,287 | 682 | 25,400 |
| Curbing | 92,319 | 1,121 | 16,298 |
| Flagging | 43,850 | 521 | 5,239 |
| Roofing slate | 12,534 | 138 | 6,842 |
| Structural and sanitary | 5,906 | 65 | 3,028 |
| Flooring slate | 6,537 | 72 | 2,450 |
| Total | 1,120,585 | 13,637 | 171,667 |

[1] Includes rubble.
[2] Includes other rough stone, and uses not specified.
[3] Includes veneer and a small amount of billiard tabletops.

## Table 8.—Dimension granite sold or used in the United States in 1985, by use

| Use | Quantity (short tons) | Cubic feet (thousands) | Value (thousands) |
|---|---|---|---|
| Rough stone: | | | |
| Rough blocks for building and construction | 102,342 | 1,238 | $8,671 |
| Irregular-shaped stone[1] | 54,870 | 628 | 2,819 |
| Monumental[2] | 227,066 | 2,502 | 22,826 |
| Dressed stone: | | | |
| Monumental[3] | 54,737 | 654 | 20,971 |
| Curbing and flagging | 93,843 | 1,136 | 16,909 |
| Other[4] | 69,375 | 830 | 21,688 |
| Total | 602,233 | [5]6,974 | 93,884 |

[1] Includes rubble.
[2] Includes small amount of unspecified rough stone.
[3] Includes small amount of stone for billiard tabletops.
[4] Includes ashlars and partially squared pieces, and slabs and blocks for building and construction.
[5] Data do not add to total shown because of independent rounding.

## Table 9.—Dimension limestone sold or used by producers in the United States in 1985, by use

| Use | Quantity (short tons) | Cubic feet (thousands) | Value (thousands) |
|---|---|---|---|
| Rough stone: | | | |
| Irregular-shaped stone[1] | 36,897 | 463 | $770 |
| Other[2] | 147,296 | 2,014 | 7,429 |
| Dressed stone: | | | |
| Monumental | 1,775 | 22 | 174 |
| Curbing | 532 | 7 | 18 |
| Other[3] | 115,775 | 1,526 | 26,505 |
| Total[4] | 302,274 | 4,033 | 34,896 |

[1] Includes rubble.
[2] Includes rough blocks for building and construction and a small amount of flagging and monumental.
[3] Includes ashlars and partially squared pieces, slabs and blocks for building and construction, a small amount of flagging, billiard tabletops, and veneer.
[4] Data may not add to totals shown because of independent rounding.

### Table 10.—Dimension sandstone sold or used by producers in the United States in 1985, by use

| Use | Quantity (short tons) | Cubic feet (thousands) | Value (thousands) |
|---|---|---|---|
| Rough stone: | | | |
| Rough blocks for building and construction | 15,685 | 212 | $377 |
| Irregular-shaped stone[1] | 54,869 | 713 | 2,144 |
| Other[2] | 4,251 | 55 | 177 |
| Dressed stone: | | | |
| Ashlars and partially squared pieces[3] | 29,465 | 389 | 2,493 |
| Slabs and blocks for building and construction | 7,300 | 100 | 1,568 |
| Flagging | 7,805 | 101 | 551 |
| Other[4] | 6,541 | 83 | 299 |
| Total[5] | 125,916 | 1,652 | 7,610 |

[1] Includes rubble.
[2] Includes flagging, other rough stone, and uses not specified.
[3] Includes veneer.
[4] Includes curbing, monumental, and billiard tabletops.
[5] Data may not add to totals shown because of independent rounding.

### Table 11.—Dimension slate sold or used by producers in the United States in 1985, by use

| Use | Quantity (short tons) | Cubic feet (thousands) | Value (thousands) |
|---|---|---|---|
| Flagging | 15,575 | 171 | $1,799 |
| Roofing slate | 12,534 | 138 | 6,342 |
| Structural and sanitary[1] | 6,018 | 66 | 3,073 |
| Flooring slate | 6,537 | 72 | 2,450 |
| Total | 40,664 | 447 | 13,664 |

[1] Includes small amount of billiard tabletops.

### Table 12.—Dimension marble sold or used by producers in the United States in 1985, by use

| Use | Quantity (short tons) | Cubic feet (thousands) | Value (thousands) |
|---|---|---|---|
| Rough stone: | | | |
| Rough blocks for building and construction | 3,496 | 39 | $747 |
| Other[1] | 15,525 | 170 | 6,945 |
| Dressed stone: | | | |
| Ashlars and partially squared pieces | 5,362 | 63 | 6,077 |
| Slabs and blocks for building and construction[2] | 9,777 | 115 | 6,890 |
| Total | 34,160 | 387 | [3]20,658 |

[1] Includes irregular-shaped stone and other rough and dressed stone.
[2] Includes small amount of flagging and monumental.
[3] Data do not add to total shown because of independent rounding.

## PRICES

The average price for dimension stone increased 14% to $153 per ton.

## FOREIGN TRADE

**Exports.**—Exports of dimension stone, about one-half of which was granite, decreased 40% in value to $14 million.

**Imports.**—Imports of dimension stone increased 32% in value to $295 million, mostly because of increases in imports of dressed granite and polished slabs of marble. Imports of polished marble slabs, mostly from Italy, increased 45% to $88 million. Imports of dressed granite increased 42% to $103.7

million, primarily because of a significant increase from Italy. On a value basis, granite accounted for 37% of imports, followed by marble, 30%; travertine, 6%; and slate, 2%.

### Table 13.—U.S. exports of dimension stone, by type

(Thousand short tons and thousand dollars unless otherwise specified)

| Type | 1984 Quantity | 1984 Value | 1985 Quantity | 1985 Value | Major destination in 1985 (percent[1]) |
|---|---|---|---|---|---|
| Granite articles | NA | 4,878 | NA | 1,388 | Canada 54%. |
| Granite, rough | 79.7 | 8,895 | 42.1 | 5,828 | Japan 52%, Canada 16%. |
| Limestone, dressed, for building or monumental | .9 | 69 | 1.0 | 116 | United Kingdom 64%. |
| Limestone articles | 34.1 | 1,593 | 2.6 | 100 | Canada 70%. |
| Marble, breccia, and onyx, rough or squared | 13.6 | 346 | 9.7 | 329 | Canada 77%. |
| Marble, breccia, and onyx articles | NA | 991 | NA | 1,191 | Canada 29%. |
| Slate building articles | NA | 177 | NA | 133 | Canada 42%. |
| Slate building articles, other | NA | 960 | NA | 1,568 | Canada 35%. |
| Stone, rough, for building or monumental | 9.8 | 1,270 | 9.8 | 1,299 | Japan 52%. |
| Stone, other, including alabaster or jet | NA | 3,828 | NA | 1,883 | Canada 24%. |
| Total | NA | r23,007 | NA | 13,835 | |

r Revised. NA Not available.

[1] By value.

Source: Bureau of the Census.

### Table 14.—U.S. imports for consumption of dimension granite, by country

(Thousand cubic feet and thousand dollars)

| Country | Rough[1] | | Dressed | | Other n.a.p.f. undecorated[2] (value) |
|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | |
| 1983 | 345 | 4,993 | 1,828 | 79,958 | 5,063 |
| 1984: | | | | | |
| Brazil | 2 | 18 | 190 | 8,527 | 156 |
| Canada | 1,249 | 4,215 | 283 | 11,102 | 2,617 |
| India | 752 | 214 | 18 | 659 | 1 |
| Italy | 11 | 325 | 2,596 | 49,955 | 1,224 |
| Japan | (3) | 2 | 9 | 159 | 20 |
| Portugal | (3) | (3) | 27 | 400 | 1 |
| Saudi Arabia | 1,976 | 95 | 59 | 134 | 108 |
| South Africa, Republic of | 259 | 415 | (3) | 17 | 3 |
| Spain | -- | -- | 230 | 4,096 | 96 |
| Other | 968 | 111 | 127 | 3,021 | 1,257 |
| Total | 5,217 | 5,395 | 3,539 | 78,070 | 5,478 |
| 1985: | | | | | |
| Brazil | 5 | 11 | 239 | 8,353 | $260 |
| Canada | 2,439 | 4,107 | 252 | 10,078 | 5,785 |
| India | 6 | 127 | 42 | 1,255 | 19 |
| Italy | 192 | 157 | 5,519 | 73,687 | 1,926 |
| Japan | -- | -- | 20 | 383 | 34 |
| Portugal | 62 | 217 | 387 | 874 | 78 |
| Saudi Arabia | 155 | 129 | 499 | 534 | 28 |
| South Africa, Republic of | 37 | 555 | 2 | 60 | -- |
| Spain | (3) | 12 | 538 | 8,626 | 54 |
| Other | 124 | 783 | 430 | 4,835 | 2,883 |
| Total[4] | 3,020 | 6,097 | 7,928 | 108,680 | 11,064 |

[1] Does not include unmanufactured, nonmonumental granite.

[2] Quantity not reported. Does not include granite n.a.p.f. decorated.

[3] Less than 1/2 unit.

[4] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

### Table 15.—Imports for consumption of major categories of dimension marble, travertine, and other calcareous stones, by country

| Country | Marble, breccia, or onyx, polished slabs |  | Marble, breccia, or onyx, other n.s.p.f.[1] [2] | Travertine dressed[3] |  |
|---|---|---|---|---|---|
|  | Quantity (thousand square feet) | Value (thousands) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1983 | 17,318 | $41,938 | $28,461 | 67,340 | $18,414 |
| 1984: |  |  |  |  |  |
| France | 918 | 1,333 | 308 | 70 | 38 |
| Germany, Federal Republic of | 178 | 304 | 579 | 18 | 4 |
| Greece | 778 | 1,266 | 336 | 5 | 1 |
| Italy | 19,354 | 42,917 | 15,978 | 135,031 | 15,000 |
| Mexico | 1,178 | 1,793 | 2,592 | 18,179 | 741 |
| Pakistan | 26 | 88 | 392 | -- | -- |
| Philippines | 222 | 441 | 94 | -- | -- |
| Portugal | 2,018 | 3,962 | 894 | 361 | 154 |
| Spain | 3,677 | 5,836 | 965 | 3,490 | 169 |
| Taiwan | 635 | 1,169 | 17,465 | 159 | 175 |
| Other | 822 | 1,848 | 1,333 | 226 | 89 |
| Total | 29,801 | 60,957 | 40,936 | 157,534 | 16,371 |
| 1985: |  |  |  |  |  |
| France | 588 | 2,021 | 1,110 | 2 | 3 |
| Germany, Federal Republic of | 427 | 483 | 375 | -- | -- |
| Greece | 1,340 | 3,086 | 310 | 2 | 2 |
| Italy | 38,573 | 60,637 | 19,627 | 168,734 | 18,088 |
| Mexico | 1,143 | 1,984 | 3,673 | 779 | 284 |
| Pakistan | 35 | 137 | 593 | -- | -- |
| Philippines | 419 | 655 | 145 | -- | -- |
| Portugal | 3,753 | 4,719 | 1,424 | 42 | 9 |
| Spain | 7,419 | 11,168 | 1,743 | 3,437 | 143 |
| Taiwan | 910 | 1,583 | 8,662 | -- | -- |
| Other | 1,529 | 2,155 | 1,860 | 7,315 | 125 |
| Total[4] | 56,137 | 88,579 | 39,521 | 180,311 | 18,654 |

[1] Does not include certain special kinds of rough marble, breccia, or onyx.
[2] Quantity not reported.
[3] Suitable for use as monumental, paving, or building stone. Does not include travertine articles.
[4] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

### Table 16.—U.S. imports for consumption of other dimension stone, by type

| Type | 1984 |  | 1985 |  | Major source in 1985 (percent[1]) |
|---|---|---|---|---|---|
|  | Quantity | Value (thousands) | Quantity | Value (thousands) |  |
| Granite, unmanufactured, nonmonumental short tons | 27,753 | $554 | 21,522 | $848 | Portugal 39%. |
| Granite, n.s.p.f., decorated | -- | 620 | -- | 402 | Italy 62%. |
| Limestone, dressed, hewn short tons | 4,855 | 612 | 15,937 | 1,145 | France 40%. |
| Marble and breccia, rough cubic feet | 57,629 | 397 | 131,755 | 609 | Italy 49%. |
| Marble, breccia, onyx, slab and tiles, unpolished square feet | 1,413,100 | 1,625 | 1,563,636 | 1,881 | Italy 55%. |
| Slate, roofing do | 1,008,911 | 597 | 1,727,961 | 926 | Spain 35%. |
| Slate, other, n.s.p.f | -- | 5,178 | -- | 6,747 | Italy 54%. |
| Travertine articles, undecorated | -- | 3,999 | -- | 6,012 | Italy 89%. |
| Travertine articles, decorated | -- | 1,489 | -- | 2,105 | Italy 96%. |
| Stone, unmanufactured short tons | 161,258 | 825 | 35,769 | 1,156 | Belgium 54%. |
| Stone, dressed, building do | 12,039 | 659 | 7,729 | 1,185 | Mexico 35%. |
| Stone, other n.s.p.f., undecorated | -- | 1,869 | -- | 1,837 | Mexico 33%. |
| Stone, other n.s.p.f., decorated | -- | 2,519 | -- | 2,646 | Mexico 25%. |

[1] By value.

Source: Bureau of the Census.

## WORLD REVIEW

Some production of dimension stone occurred in most countries of the world. As usual, Italy produced about one-half of the world's total. Other significant producers were Brazil, Finland, India, Norway, Portugal, Spain, Sweden, Turkey, and the United States.

**Canada.**—Canadian production of dimension stone, mostly granite, expanded substantially in the last several years because modern finishing plants with new European equipment came on-stream or will do so shortly. Granicor Inc. brought on-stream a new plant equipped with European saws and polishing equipment in Quebec, resulting in the opening of six new granite quarries in the Province. Karnuk Marble Industries Inc. announced plans to establish a similar plant in Cornwall, Ontario. RPS Marble Limitee announced a $7 million expansion and modernization of its dimension stone finishing facilities, to be partly paid for by a grant of $1.4 million from La Société de Developpement Industrial du Quebec.

**China.**—Local authorities announced the discovery of a black marble deposit with reserves of 22 million tons near Tuoyaoling, Jilin Province. The authorities announced plans to develop the deposit.

The Provincial Geological Department of Hebei Province announced that it discovered over 7 billion cubic feet of marble reserves in 20 counties of the Province. Reserves of more than 50 different varieties of marble are available, with many of them presently being quarried and processed. The provincial authorities indicated that they plan to quarry over 35 million cubic feet of marble each year in the Baoding area alone and to import Italian quarrying and processing equipment. Some of these stones have appeared in European markets.

**Ethiopia.**—The Ethio-Libyan Joint Mining Co. began mining large reserves of pure white fine-grained marble with a hint of translucency called Boka White. It is being quarried from 16 sites in the Mendi District in the western part of Wollega Province, near the Sudanese border. The firm, which is only 4 years old, planned to produce about 350,000 cubic feet of marble per year. It also announced plans to build a finishing plant in central Ethiopia to make marble tiles. The firm also indicated that it produced 210,000 cubic feet of good quality granite blocks, including some of a black granite and pink granite. The marble and the black and pink granite were commercially available on European markets.

**Finland.**—Outokumpu Oy expanded its activities into dimension granite by founding a subsidiary, Granite Products Ltd., with a granite deposit in Taivassalo, in southwestern Finland. The firm planned to open a quarry and bring Finland's first finishing plant on-stream in 1985. Production was scheduled to be in a range from 105,000 to 175,000 cubic feet. The plant will cost $5 million. Finland has been a major exporter of rough granite blocks, mostly to European destinations.

**Greece.**—The Drama-Kavala area produced 3.15 million cubic feet of white and white-gray marbles, much of which was exported as rough blocks and finished products. The Ioannina area produced 1.75 million cubic feet of beige marble, almost all of which was consumed domestically. The Argolis area produced 1.40 million cubic feet of beige, brown, and red marbles, most of which was finished in Athens. The Attica area produced 0.72 million cubic feet of white (Pentelikos) and ash-blue marble, most of which was exported. The major firms are Hellenic Chemical Products and Fertilizers Co. Ltd., Kavala Marbles S.A., and Skaris Marble S.A.[3]

**Jamaica.**—Marble production is presently quite small, but fairly sizable reserves would allow it to be expanded. The small amounts now being produced were used locally for mosaic slabs and tiles, tabletops, bar counters, and terrazzo tiles. There are a number of deposits, but only the Serge Island deposit has been explored. The upper 15 feet of this deposit was severely shocked by unnecessary blasting during past quarrying and would probably not be commercially usable as a dimension stone. The large amount of material beneath this upper layer, down to at least 150 feet, is high grade, competent, and quarriable. The material found acceptance in the North American market before 1965 and, therefore, was believed to be ready for commercialization.[4]

**Saudi Arabia.**—The Saudi Arabian Government continued its dimension stone program. Eight model quarries in the western part of the country near the Red Sea were operated. Most of the quarries were worked for granite, two for anorthosite, and one for limestone. The stone was made into slabs for building at two pilot finishing plants at Jiddah. Exploration continued to add to existing sizable reserves.

**Spain.**—The Instituto Geologico y Minero de España issued its latest figures for marble production by geographic unit. Of the total quantity of marble produced in 1980, 25.4% originated in Alicante Province in the Levantine Region, 19.3% in Murcia Province in the Levantine Region, 13.8% in Barcelona Province of the Catalonia Region, 9.7% in Almería Province, 7.6% in Navarra Province of the North Region, 7.4% in Valencia Province of the Levantine Region, and the balance in other Provinces.

**United Kingdom.**—The British slate industry prospered and expanded in 1985. Penrhyn Quarries, part of the Alfred McAlpine Minerals group, bought the Buttermere & Westmorland Green Slate Co. Ltd. of Borrowdale, Cumbria. This firm had an underground green slate quarry, which has been operated since 1753, at the top of the Honister Pass and a small plant that produced flooring, roofing, and other slate products. Plans called for developing reserves and increasing production of roofing and architectural slate, with some of the production to go to the U.S. market. The firm planned to buy another quarry in Cumbria. Penrhyn Quarries also bought the Hilltop Slate plant and quarries in New York and Vermont. Penrhyn Quarries Welsh quarry produced a number of colors of slate, but blue and plum were the most important. The installation of new saws and equipment was planned for the plant at the quarry site. Production at the Welsh quarry expanded since 1982. Published data indicate that Penrhyn Quarries produced 13,200 tons of roofing slate and 15,400 tons of architectural slate in 1984, compared with a total British production of 24,200 tons of roofing slate in 1984. British production of nonroofing types of slate increased markedly in the last several years.[5]

Delabole Slate Ltd., a subsidiary of Carnon Consolidated Ltd., expanded its quarry in Cornwall and brought it up to modern quarrying standards. When completed, the firm planned to expand production capacity by renovating the plant with the latest Italian equipment and installing diamond wire saws in the quarry.

Burlington Slate Ltd. began a $1.5 million effort to upgrade equipment and to consolidate all its processing at the Kirkby-in-Furness plant. The roofing section with its three new circular saws was already onstream. Production continued from most or all of the presently operating quarries scattered about Cumbria. The newly equipped roofing section of the plant was expected to almost double output per employee. The balance of the new plant, featuring two Italian 30-blade frame saws and two more large circular saws, was expected to be on-stream in late 1985. Some finishing equipment will also be added, such as a flame-texturing machine.[6] After the new equipment is installed, the product mix would shift from roofing slate toward architectural slate.

Burlington Slate has been a very active exporter in the last several years. It recently supplied China with $180,000 worth of polished slate flooring for a museum, despite the fact that China itself is a major producer and exporter of slate. According to published data, Burlington Slate produced 4,950 tons of roofing slate and 3,000 tons of architectural slate in 1984, 30% to 40% of which was exported.[7]

Dimension stone quarrying in Scotland has revived in the last few years, mostly because of a need to restore buildings built of Scottish stone. The creamy brown Newbigging sandstone was first returned to production to restore a Swedish cathedral and now will continue to be produced for use in the new National Library of Scotland building. The whitish gray Dunmore sandstone was produced to restore a hunting lodge and will be used in an office redevelopment project in Edinburgh. The red Ross of Mull granite was quarried again, but with no specific restoration or other market in mind.[8]

## TECHNOLOGY

A Bureau of Mines study on the use of geotechnology to identify and reduce ground control hazards at slate quarries was published. The study was performed at one quarry in eastern Pennsylvania. The major hazard covered was falling rock attributable to weathered bedding plane faults. Results indicated that the bedding plane faults can be detected outside the quarry perimeter by using surface resistivity measurements. The other major hazard, falls of ice from quarry highwalls, was found to be rectifiable using water diversion as the basic control method. In situ stresses were usually a minor problem in slate extraction, although they could interact with developed stresses to result in failure of barriers between quarries. Pull tests showed that loose rock can be secured by rockbolts, which anchor firmly in the slate.[9]

A conference on the "Degradation of Materials Due to Acid Rain" was held in response to a rising concern about the damage caused by acid pollutants to concrete, dimension stone, metals, paint, and wood. The Environmental Protection Agency estimated that the damage would total at least $5 billion per year. Acid pollutants are known to attack limestone and marble in ancient monuments like the Acropolis. This fact has been verified by preliminary results from experiments now under way. It is believed that granite and sandstone also are probably vulnerable to attack. The precise causes of the damage and the processes by which it happens are not clear, but the completion of experiments now under way may increase the understanding of atmospheric degradation of stone.[10]

The deterioration of marble in tombstones was studied in the New York City area. Tombstone thickness and depth of emblem inscription were measured in two cemeteries, one in an industrial area in New York City and one in a semirural area on Long Island. Weathering rates were higher in the industrial area. Sulfur dioxide concentrations from 1880 to 1980 were estimated for New York City from a retrospective air quality model and were found to have a linear relationship with the weathering rates. The weathering coefficient for New York City was determined to be one-half inch, per century, per part per million of sulfur dioxide for fine-grained marble.[11]

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# Sulfur

## By David E. Morse[1]

The United States retained its position as the world's largest sulfur producer, with an increased output of sulfur in all forms of nearly 1 million metric tons compared with that of 1984. Output from Frasch mines increased 20%, exceeding 5 million tons for the first time since 1981. Production of recovered elemental sulfur from petroleum refineries and natural-gas-processing plants increased to an all-time high and was over 5 million tons for the second consecutive year. Domestic demand continued to exceed production, and the United States remained a net sulfur importer. Shipments of sulfur in all forms from domestic producers decreased about 200,000 tons; production surpassed shipments by nearly 400,000 tons.

Apparent consumption of elemental sulfur from all sources declined 7%. Shipments of Frasch sulfur to domestic consumers, however, declined 10% and supplied 35% of elemental demand. The average annual price for all elemental sulfur increased domestically and worldwide despite a drop in world spot pricing during the final 4 months of the year.

**Table 1.—Salient sulfur statistics**

(Thousand metric tons, sulfur content, and thousand dollars unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production: | | | | | |
| Frasch | 6,348 | 4,210 | 3,202 | 4,198 | 5,011 |
| Recovered[1] | 4,259 | 4,404 | 4,955 | 5,214 | 5,313 |
| Other forms | 1,538 | 1,173 | 1,133 | 1,245 | 1,285 |
| Total | 12,145 | 9,787 | 9,290 | 10,652 | 11,609 |
| Shipments: | | | | | |
| Frasch | 5,910 | 3,598 | 4,111 | 5,001 | 4,678 |
| Recovered[1] | 4,207 | 4,344 | 5,041 | 5,210 | 5,266 |
| Other forms | 1,538 | 1,173 | 1,133 | 1,245 | 1,285 |
| Total | 11,655 | 9,115 | 10,285 | 11,456 | 11,229 |
| Imports, elemental | 2,522 | 1,905 | 1,695 | 2,557 | 2,104 |
| Exports, elemental[2] | 1,392 | 961 | 992 | 1,334 | 1,365 |
| Consumption, apparent, all forms | 12,785 | 10,059 | 10,988 | 12,679 | 11,968 |
| Stocks, Dec. 31: Producer, Frasch and recovered | $^{r}$3,546 | $^{r}$4,218 | $^{r}$3,223 | $^{r}$2,419 | 2,799 |
| Value: | | | | | |
| Shipments, f.o.b. mine or plant: | | | | | |
| Frasch | $715,683 | $434,660 | $414,210 | $546,106 | $573,570 |
| Recovered[1] | 412,115 | 425,217 | 384,214 | 416,878 | 485,084 |
| Other forms | 140,618 | 122,177 | 116,255 | 121,692 | 123,937 |
| Total | 1,268,416 | 982,054 | 914,679 | 1,084,676 | 1,182,591 |
| Imports, elemental[3] | $209,766 | $164,885 | $129,110 | $200,189 | $199,240 |
| Exports, elemental[4] | $187,407 | $122,143 | $109,298 | $156,067 | $189,248 |
| Price, elemental, dollars per metric ton, f.o.b. mine or plant | $111.48 | $108.27 | $87.24 | $94.31 | $106.46 |
| World: Production, all forms (including pyrites) | $^{r}$53,550 | $^{r}$50,870 | 50,530 | $^{p}$52,607 | $^{e}$54,856 |

$^{e}$Estimated. $^{p}$Preliminary. $^{r}$Revised.

[1] Includes Puerto Rico and the Virgin Islands.

[2] Includes exports from the Virgin Islands to foreign countries.

[3] Declared customs valuation.

[4] Includes value of exports from the Virgin Islands to foreign countries.

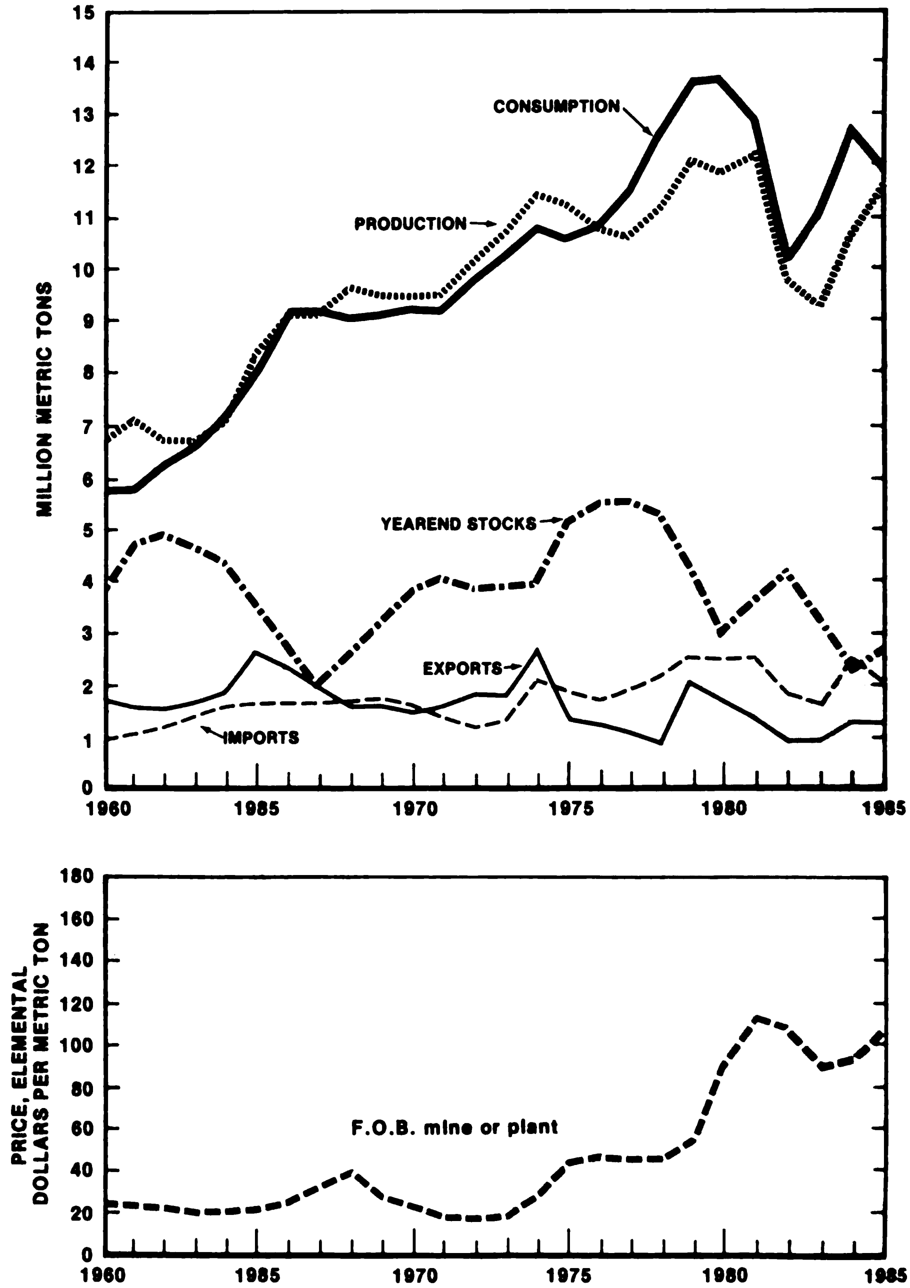

Figure 1.—Trends in the sulfur industry in the United States.

World sulfur production continued to recover from the depressed levels of 1982 and 1983, but failed to satisfy world demand, which required a drawdown from inventories of about 2 million tons. This inventory reduction was less severe than the 3- and 4-million-ton reductions in 1983 and 1984, respectively.

**Domestic Data Coverage.**—Domestic production data for sulfur are developed by the Bureau of Mines from four separate, voluntary surveys of U.S. operations. Typical of these surveys is the "Elemental Sulfur" survey. Of the 190 operations to which a survey request was sent, all responded, representing 100% of the total production shown in tables 1 and 2.

## DOMESTIC PRODUCTION

Sulfur is one of the few elements that occurs in nature in the native, or elemental, state. It also occurs combined with iron and base metals as sulfide minerals, and with the alkali metals and alkali earths as sulfate minerals. In coal and petroleum, sulfur is found in a variety of complex organosulfur compounds, and in natural gas, as hydrogen sulfide ($H_2S$) gas. Commercial production of sulfur, either as elemental sulfur or combined in another chemical form, in the United States is accomplished by a variety of methods dictated by the sulfur source. Native sulfur in sedimentary deposits or associated with the caprocks of salt domes is mined by the Frasch hot water process, in which the sulfur is melted underground and brought to the surface with an airlift. Sulfur from iron and base metal sulfides is usually recovered as sulfuric acid during roasting or smelting. Sulfur from coal may be recovered in the elemental form or as ammonium sulfate during the production of coke; as sulfuric acid or sulfur dioxide when burning coal; or when producing low-British-thermal-unit coal gas, as ammonium sulfate while scrubbing the gas with ammonia. Sulfur is recovered from petroleum and natural gas by absorbing the $H_2S$ in an amine solution, then regenerating $H_2S$, and processing it into elemental sulfur in a Claus converter.

**Frasch.**—In January, the United States had five Frasch mines operating in Texas and Louisiana. Mines in Louisiana were Freeport Minerals Co. at Garden Island Bay on the Mississippi River Delta and Grand Isle, 7 miles offshore in the Gulf of Mexico. Companies in Texas were Farmland Industries Inc. at Fort Stockton; Pennzoil Sulphur Co., formerly Duval Corp., a subsidiary of Pennzoil Co. renamed in 1985, at Culberson; and Texasgulf Chemicals Co. at Boling Dome in Wharton County. Farmland discontinued operations at its Fort Stockton facility in March because of sulfur reserve depletion. Texasgulf's Comanche Creek, TX, facility was idle for the entire year. Freeport announced that Frasch operations would be undertaken in 1986 at its Caminada Pass, LA, property, which had last produced sulfur in 1968. At yearend 1985, the Frasch mining industry was operating at about 90% of capacity.

Frasch sulfur output increased 800,000 tons over the depressed quantity produced in 1984. Shipments to domestic and overseas consumers, however, declined by 300,000 tons. Frasch sulfur accounted for about 43% of domestic production in 1985, compared with 39% in 1984. Approximately 79% of Frasch sulfur shipments was for domestic consumption, and 21% for export.

**Recovered.**—Production of recovered elemental sulfur, a nondiscretionary byproduct from petroleum refining, natural gas processing, and coking plants, accounted for 46% of the total domestic output of sulfur in all forms, compared with 49% in 1984. Production and shipments reached all-time highs exceeding 5.25 million tons because of record-high production from petroleum refineries. A decline in output from natural gas plants in Florida and Mississippi was partially offset by increased production from plants in Wyoming. This designated type of sulfur was produced by 54 companies at 155 plants in 26 States, 1 plant in Puerto Rico, and 1 plant in the U.S. Virgin Islands. Most of these plants were of relatively small size, with only 11 reporting annual production exceeding 100,000 tons. By source, 55% was produced at 84 refineries or satellite plants treating refinery gases and 3 coking plants, and 45% was produced by 26 companies at 68 natural gas treatment plants. The five largest recovered-sulfur-producing companies were Chevron U.S.A. Inc., Exxon Co. U.S.A., Shell Oil Co., Standard Oil Co. of Indiana, and Texaco Inc. These companies' 59 plants accounted for 63% of recovered elemental sulfur output during the year.

The leading States in production of recovered sulfur were California, Louisiana, Mississippi, Texas, and Wyoming. These five States contributed 71% of total output; shipments from Texas accounted for 28% of total recovered sulfur shipments. The total value of recovered sulfur shipments increased 16% compared with that of 1984.

### Table 2.—Production of sulfur and sulfur-containing raw materials in the United States

(Thousand metric tons)

| | 1984 | | 1985 | |
|---|---|---|---|---|
| | Gross weight | Sulfur content | Gross weight | Sulfur content |
| Frasch sulfur | 4,193 | 4,193 | 5,011 | 5,011 |
| Recovered sulfur[1] | 5,214 | 5,214 | 5,313 | 5,313 |
| Byproduct sulfuric acid (100% basis) produced at copper, lead, molybdenum, and zinc plants | 2,942 | 962 | 2,928 | 957 |
| Other forms[2] | 723 | 283 | 814 | 328 |
| Total | XX | 10,652 | XX | 11,609 |

XX Not applicable.

[1] Includes Puerto Rico and the Virgin Islands.

[2] Includes hydrogen sulfide, liquid sulfur dioxide, and pyrites.

### Table 3.—Sulfur produced and shipped from Frasch mines in the United States

(Thousand metric tons and thousand dollars)

| Year | Production | | | Shipments | |
|---|---|---|---|---|---|
| | Texas | Louisiana | Total[1] | Quantity | Value[2] |
| 1981 | 3,908 | 2,440 | 6,348 | 5,910 | 715,683 |
| 1982 | 2,898 | 1,312 | 4,210 | 3,598 | 434,660 |
| 1983 | 1,915 | 1,286 | 3,202 | 4,111 | 414,210 |
| 1984 | 2,257 | 1,937 | 4,193 | 5,001 | 546,106 |
| 1985 | 2,940 | 2,071 | 5,011 | 4,678 | 573,570 |

[1] Data may not add to totals shown because of independent rounding.

[2] F.o.b. mine.

### Table 4.—Recovered sulfur produced and shipped in the United States[1]

(Thousand metric tons and thousand dollars)

| Year | Production | | | Shipments | |
|---|---|---|---|---|---|
| | Natural gas plants | Petroleum refineries[2] | Total | Quantity | Value[3] |
| 1981 | 1,971 | 2,288 | 4,259 | 4,207 | 412,115 |
| 1982 | 1,960 | 2,444 | 4,404 | 4,344 | 425,217 |
| 1983 | 2,371 | 2,584 | 4,955 | 5,041 | 384,214 |
| 1984 | 2,407 | 2,807 | 5,214 | 5,210 | 416,878 |
| 1985 | 2,373 | 2,940 | 5,313 | 5,266 | 485,084 |

[1] Includes Puerto Rico and the Virgin Islands.

[2] Includes a small quantity from coking operations and utility plants in 1981-82; includes only a small quantity from coking operations in 1983-85.

[3] F.o.b. plant.

### Table 5.—Recovered sulfur produced and shipped in the United States, by State

(Thousand metric tons and thousand dollars)

| State | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Production (quantity) | Shipments | | Production (quantity) | Shipments | |
| | | Quantity | Value | | Quantity | Value |
| Alabama | 380 | 380 | 34,492 | 370 | 367 | 35,421 |
| California | 516 | 516 | 28,695 | 590 | 576 | 47,087 |
| Florida | 111 | 111 | W | 91 | 91 | W |
| Illinois | 182 | 181 | 15,838 | 193 | 194 | 19,895 |
| Louisiana | 320 | 318 | 29,901 | 405 | 403 | 45,053 |
| Michigan and Minnesota | 139 | 139 | 9,627 | 137 | 138 | 11,623 |
| Mississippi | 745 | 754 | 74,382 | 578 | 565 | 62,156 |
| New Jersey | 58 | 59 | 6,636 | 74 | 74 | 9,357 |
| New Mexico | 63 | 63 | 4,245 | 55 | 55 | 4,281 |
| North Dakota | 112 | 112 | 5,572 | 108 | 109 | 6,127 |
| Ohio | 39 | 39 | 3,983 | 36 | 36 | 3,891 |
| Pennsylvania | 53 | 52 | 4,487 | 50 | 50 | 4,475 |
| Texas | 1,417 | 1,413 | 121,447 | 1,500 | 1,496 | 147,426 |
| Wisconsin | 2 | 2 | 108 | 1 | 2 | 96 |
| Wyoming | 626 | 624 | 23,280 | 703 | 699 | 35,335 |
| Other[1] | 453 | 447 | 54,185 | 420 | 411 | 52,862 |
| Total[2] | 5,214 | 5,210 | 416,878 | 5,313 | 5,266 | 485,084 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes Arkansas, Colorado, Delaware, Indiana, Kansas, Kentucky, Montana, Utah, Virginia, Washington, Puerto Rico, the Virgin Islands, and data indicated by symbol W.

[2] Data may not add to totals shown because of independent rounding.

### Table 6.—Recovered sulfur produced and shipped in the United States, by Petroleum Administration for Defense (PAD) district

(Thousand metric tons)

| District and source | 1984 | | 1985 | |
|---|---|---|---|---|
| | Production | Shipments | Production | Shipments |
| PAD 1: | | | | |
| Petroleum and coke | 228 | 228 | 230 | 227 |
| Natural gas | 110 | 111 | 91 | 91 |
| Total[1] | 339 | 339 | 321 | 318 |
| PAD 2: | | | | |
| Petroleum and coke | 504 | 500 | 495 | 495 |
| Natural gas | 114 | 114 | 111 | 112 |
| Total[1] | 618 | 615 | 606 | 608 |
| PAD 3:[2] | | | | |
| Petroleum | 1,440 | 1,443 | 1,498 | 1,468 |
| Natural gas | 1,565 | 1,563 | 1,476 | 1,479 |
| Total[1] | 3,006 | 3,007 | 2,975 | 2,948 |
| PAD 4 and 5: | | | | |
| Petroleum | 633 | 633 | 715 | 700 |
| Natural gas | 616 | 613 | 693 | 690 |
| Total[1] | 1,250 | 1,247 | 1,408 | 1,390 |
| Grand total[1] | 5,214 | 5,210 | 5,313 | 5,266 |

[1] Data may not add to totals shown because of independent rounding.

[2] Includes Puerto Rico and the Virgin Islands.

**Byproduct Sulfuric Acid.**—Sulfur contained in byproduct sulfuric acid produced at copper, lead, molybdenum, and zinc roasters and smelters amounted to 8% of the total domestic production of sulfur in all forms. Production was essentially the same as that of 1984 despite the closure of three copper, one lead, and one zinc smelter during 1985. A copper smelter in Washington and another in Arizona were closed permanently because the cost for installation of pollution control systems, required by Federal law, had rendered the facilities uneconomic in terms of existing and projected copper prices. Ten acid plants operated in conjunction with copper smelters, and 11 were accessories to lead, molybdenum, and zinc smelting and roasting operations. The five largest acid plants accounted for 67% of the output, and production in five States was 84% of the total. The five largest producers of byproduct sulfuric acid were ASARCO Incorporated, Inspiration Consolidated Copper Co., Kennecott, Magma Copper Co., and Phelps Dodge Corp. These companies' 13 plants produced 81% of the total.

### Table 7.—Byproduct sulfuric acid[1] produced in the United States

(Thousand metric tons, sulfur content, and thousand dollars)

| Year | Copper plants[2] | Zinc plants[2] | Lead and molybdenum plants[3] | Total | Value |
|---|---|---|---|---|---|
| 1981 | 848 | 179 | 132 | 1,159 | 75,657 |
| 1982 | 615 | 112 | 101 | 828 | 63,674 |
| 1983 | 601 | 126 | 104 | 831 | 54,995 |
| 1984 | 736 | 145 | 81 | 962 | 59,098 |
| 1985 | 729 | 141 | 87 | 957 | 56,299 |

[1] Includes acid from foreign materials.
[2] Excludes acid made from pyrites concentrates.
[3] Excludes acid made from native sulfur.

**Pyrites, Hydrogen Sulfide, and Sulfur Dioxide.**—Contained sulfur in these products represented 3% of the total domestic production of sulfur in all forms. The total sulfur contained in these products was 16% greater than that of 1984. The three largest producers were Shell Oil Co., Stauffer Chemical Co., and Tennessee Chemical Co. These three companies' mines and plants accounted for 98% of the total contained sulfur in the form of these products.

### Table 8.—Pyrites, hydrogen sulfide, and sulfur dioxide sold or used in the United States

(Thousand metric tons, sulfur content, and thousand dollars)

| Year | Pyrites | Hydrogen sulfide | Sulfur dioxide | Total | Value |
|---|---|---|---|---|---|
| 1981 | 307 | 28 | 44 | 379 | 64,961 |
| 1982 | 265 | 32 | 48 | 345 | 58,503 |
| 1983 | W | W | 50 | 302 | 61,260 |
| 1984 | W | W | 45 | 283 | 62,594 |
| 1985 | W | W | 43 | 328 | 67,638 |

W Withheld to avoid disclosing company proprietary data; included in "Total."

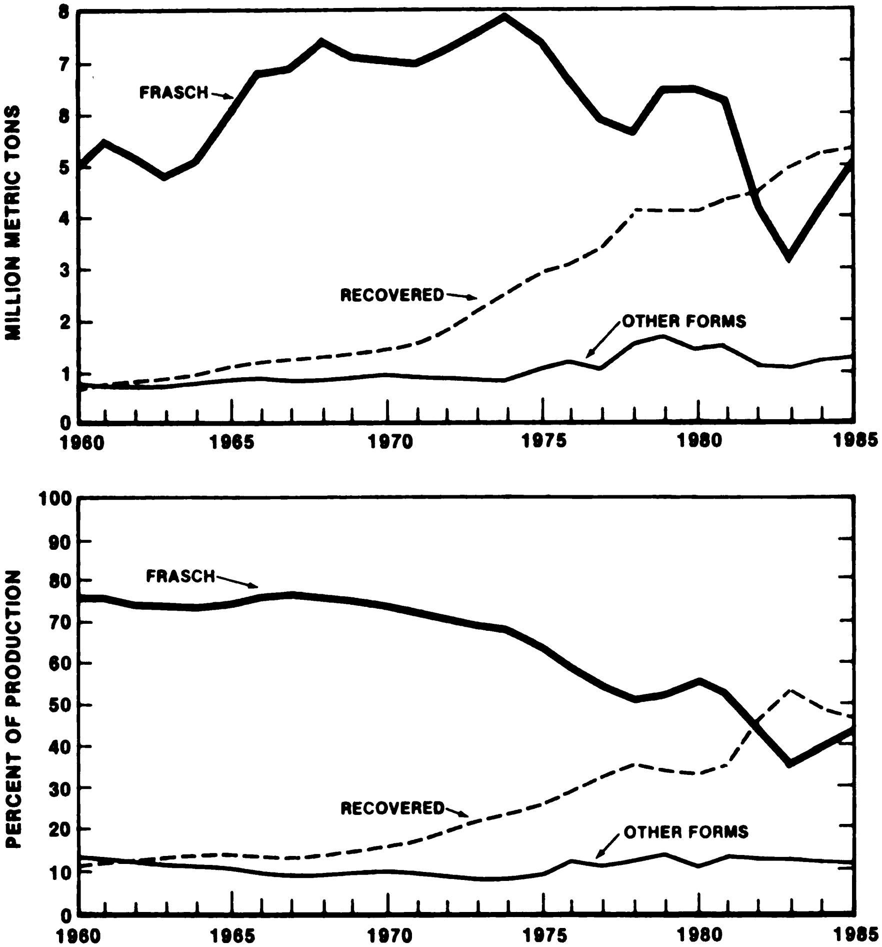

Figure 2.—Trends in the production of sulfur in the United States.

## CONSUMPTION AND USES

Sulfur is a relatively unusual mineral commodity because most of it is converted to a chemical intermediate, sulfuric acid, for use in a myriad of chemical processes. Usually, the sulfur values do not become constituents of the final chemical product but are retained either in a byproduct or as wastes requiring disposal in an environmentally acceptable manner. In 1985, sulfuric acid retained its position, both domestically and worldwide, as the most universally used mineral acid and the largest volume inorganic chemical in terms of the quantity produced and consumed annually.

Apparent domestic consumption of sulfur in all forms decreased from that of 1984. Eighty-three percent of the sulfur consumed was obtained from domestic sources compared with 80% in 1984. The sources of supply in 1985 were domestic recovered elemental sulfur, 41%; domestic Frasch sulfur, 31%; and combined domestic byproduct sulfuric acid, pyrites, hydrogen sulfide, and sulfur dioxide, 11%. The remaining 17% was supplied by imports of Frasch and recovered elemental sulfur.

The Bureau of Mines collected end-use data on sulfur and sulfuric acid according to the Standard Industrial Classification of industrial activities. Shipments by end use of elemental sulfur were reported by 58 companies, and shipments of sulfuric acid were reported by 57 companies. Eleven companies reported shipments of both elemental sulfur and sulfuric acid.

The largest sulfur end use, sulfuric acid, represented 82% of shipments for domestic consumption. Some identified end uses were tabulated in the "Unidentified" category because these data were proprietary. Data collected from companies that did not identify shipments by end use were also tabulated as "Unidentified." Although supporting data are unavailable, it could be reasonably assumed that a significant portion of the sulfur in the "Unidentified" category could have been shipped to sulfuric acid producers or exported. The difference between exports reported in the Bureau canvass and exports of 1,365,000 tons reported by the Bureau of the Census may have been caused by differences in accounting between company records and compilations of the Census Bureau, or by sales to other parties that exported sulfur and were not included in the Bureau of Mines canvass.

Shipments of 100% sulfuric acid declined slightly because production of phosphatic fertilizers, the largest single end use of sulfuric acid, decreased. Most of the falloff in demand, which occurred during the final 4 months, was a direct result of decreased fertilizer sales to domestic farmers while the U.S. Congress was debating the Food Security Act of 1985. Shipments of sulfuric acid for petroleum refining and other petroleum and coal products, the second largest end use, increased slightly. Usage of sulfuric acid for copper ore leaching was over 1 million tons for the second consecutive year, significantly higher than in 1982 and 1983, because of U.S. copper producers' attempts to lower their costs of production. Copper from leaching was considerably less expensive than copper from conventional smelting.

According to the 1985 canvass reports, company receipts of spent or contaminated sulfuric acid for reclaiming totaled 3 million tons. The largest source of this spent acid continued to be the petroleum refining industry, which accounted for 51% of the total returned. The petroleum refining industry was a net user of 700,000 tons of sulfuric acid. About 750,000 tons of spent acid was reclaimed from plastic and synthetic materials operations. The remaining reclaimed acid was returned from manufacturers of soaps and detergents, steel, industrial organic chemicals, other chemical products, storage batteries, synthetic rubber, agricultural chemicals, and some unidentified sources.

The largest use of sulfur in all forms, for agricultural purposes, decreased to nearly 8.6 million tons. Industrial use was also lower.

### Table 9.—Apparent consumption of sulfur[1] in the United States

(Thousand metric tons)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Frasch: | | | | | |
| Shipments | 5,910 | 3,598 | 4,111 | 5,001 | 4,678 |
| Imports | 856 | 690 | 604 | 722 | 724 |
| Exports | 1,216 | 731 | 601 | r911 | 986 |
| Total | 5,550 | 3,557 | 4,114 | r4,812 | 4,416 |
| Recovered: | | | | | |
| Shipments[2] | 4,207 | 4,344 | 5,041 | 5,210 | 5,266 |
| Imports | 1,666 | 1,215 | 1,091 | 1,835 | 1,380 |
| Exports | 176 | 230 | 391 | r423 | 379 |
| Total | 5,697 | 5,329 | 5,741 | r6,622 | 6,267 |
| Pyrites, shipments | 307 | 265 | W | W | W |
| Byproduct sulfuric acid, shipments | 1,159 | 828 | 831 | 962 | 957 |
| Other forms, shipments[3] | 72 | 80 | 302 | 283 | 328 |
| Total, all forms | 12,785 | 10,059 | 10,988 | 12,679 | 11,968 |

r Revised. W Withheld to avoid disclosing company proprietary data; included with "Other forms, shipments."

[1] Crude sulfur or sulfur content.

[2] Includes Puerto Rico and the Virgin Islands.

[3] Includes consumption of hydrogen sulfide, liquid sulfur dioxide, and data indicated by symbol W.

## Table 10.—Elemental sulfur sold or used in the United States, by end use

(Thousand metric tons)

| SIC | End use | Quantity 1984 | Quantity 1985 |
|---|---|---|---|
| 20 | Food and kindred products | W | W |
| 26, 261 | Pulp and paper products | 29 | 27 |
| 282, 2822, 2823 | Synthetic rubber, cellulosic fibers,[1] other plastic products | 65 | 25 |
| 287 | Agricultural chemicals | 480 | 579 |
| 28, 2816, 285, 286 | Paint and allied products, inorganic pigments,[2] industrial organic chemicals, other chemical products | 127 | 105 |
| 284 | Soaps and detergents | 14 | 31 |
| 29, 291 | Petroleum refining and petroleum and coal products | 278 | 189 |
| 281 | Other industrial inorganic chemicals | 285 | 222 |
| 30 | Rubber and miscellaneous plastic products | W | W |
| | Sulfuric acid: | | |
| | Domestic sulfur | 6,909 | 6,880 |
| | Imported sulfur | 2,425 | 2,052 |
| | Total | 9,334 | 8,932 |
| | Unidentified | 734 | 738 |
| | Total domestic uses | 11,346 | 10,843 |
| | Exports | 1,289 | 1,112 |
| | Grand total | 12,635 | 11,955 |

W Withheld to avoid disclosing company proprietary data; included with "Unidentified."

[1] Includes cellulosic fibers in 1984.

[2] Includes inorganic pigments in 1985.

## Table 11.—Sulfuric acid sold or used in the United States, by end use

(Thousand metric tons of 100% $H_2SO_4$)

| SIC | End use | Quantity 1984 | Quantity 1985 |
|---|---|---|---|
| 102 | Copper ores | 1,043 | 1,018 |
| 1094 | Uranium and vanadium ores | 163 | 62 |
| 10 | Other ores | 194 | 54 |
| 261 | Pulpmills | 700 | 705 |
| 26 | Other paper products | 114 | 89 |
| 285, 2816 | Inorganic pigments and paints and allied products | 332 | 331 |
| 281 | Other inorganic chemicals | 1,160 | 834 |
| 282, 2822 | Synthetic rubber and other plastic materials and synthetics | 959 | 742 |
| 2823 | Cellulosic fibers including rayon | 155 | 129 |
| 283 | Drugs | 74 | 52 |
| 284 | Soaps and detergents | 254 | 272 |
| 286 | Industrial organic chemicals | 938 | 1,010 |
| 2873 | Nitrogenous fertilizers | 261 | 191 |
| 2874 | Phosphatic fertilizers | 26,373 | 24,082 |
| 2879 | Pesticides | 70 | 74 |
| 287 | Other agricultural chemicals | 47 | 64 |
| 2892 | Explosives | 118 | 94 |
| 2899 | Water-treating compounds | 213 | 291 |
| 28 | Other chemical products | 405 | 151 |
| 29, 291 | Petroleum refining and other petroleum and coal products | 2,067 | 2,215 |
| 30 | Rubber and miscellaneous plastic products | W | 11 |
| 331 | Steel pickling | 270 | 212 |
| 333 | Nonferrous metals | 50 | 56 |
| 33 | Other primary metals | 113 | 161 |
| 3691 | Storage batteries (acid) | 177 | 206 |
| | Unidentified | 1,584 | 1,613 |
| | Total domestic | 37,834 | 34,719 |
| | Exports | 61 | 69 |
| | Grand total | 37,895 | 34,788 |

W Withheld to avoid disclosing company proprietary data; included with "Unidentified."

## Table 12.—Sulfur and sulfuric acid sold or used in the United States, by end use

(Thousand metric tons, sulfur content)

| SIC | End use | Elemental sulfur[1] |  | Sulfuric acid (sulfur equivalent) |  | Total |  |
|---|---|---|---|---|---|---|---|
|  |  | 1984 | 1985 | 1984 | 1985 | 1984 | 1985 |
| 102 | Copper ores | -- | -- | 341 | 333 | 341 | 333 |
| 1094 | Uranium and vanadium ores | -- | -- | 53 | 20 | 53 | 20 |
| 10 | Other ores | -- | -- | 63 | 18 | 63 | 18 |
| 20 | Food and kindred products | W | W | -- | -- | W | W |
| 26, 261 | Pulpmills and paper products | 29 | 27 | 266 | 259 | 295 | 286 |
| 28, 285, 286, 2816 | Inorganic pigments, paints and allied products, industrial organic chemicals, other chemical products | [2]127 | 105 | 109 | 109 | 236 | 214 |
| 281 | Other inorganic chemicals | 285 | 222 | 379 | 273 | 664 | 495 |
| 282, 2822 | Synthetic rubber and other plastic materials and synthetics | [3]65 | 25 | 314 | 243 | [3]379 | 268 |
| 2823 | Cellulosic fibers, including rayon | (4) | -- | 51 | 42 | 51 | 42 |
| 283 | Drugs | -- | -- | 24 | 17 | 24 | 17 |
| 284 | Soaps and detergents | 14 | 31 | 83 | 89 | 97 | 120 |
| 286 | Industrial organic chemicals | -- | -- | 307 | 330 | 307 | 330 |
| 2873 | Nitrogenous fertilizers | -- | -- | 85 | 62 | 85 | 62 |
| 2874 | Phosphatic fertilizers | -- | -- | 8,621 | 7,872 | 8,621 | 7,872 |
| 2879 | Pesticides | -- | -- | 23 | 24 | 23 | 24 |
| 287 | Other agricultural chemicals | 480 | 579 | 15 | 21 | 495 | 600 |
| 2892 | Explosives | -- | -- | 39 | 31 | 39 | 31 |
| 2899 | Water-treating compounds | -- | -- | 70 | 95 | 70 | 95 |
| 28 | Other chemical products | -- | -- | 132 | 49 | 132 | 49 |
| 29, 291 | Petroleum refining and other petroleum and coal products | 278 | 189 | 676 | 724 | 954 | 913 |
| 30 | Rubber and miscellaneous plastic products | W | W | W | 4 | W | 4 |
| 331 | Steel pickling | -- | -- | 88 | 69 | 88 | 69 |
| 333 | Nonferrous metals | -- | -- | 16 | 18 | 16 | 18 |
| 33 | Other primary metals | -- | -- | 37 | 53 | 37 | 53 |
| 3691 | Storage batteries (acid) | -- | -- | 58 | 67 | 58 | 67 |
|  | Exported sulfuric acid | -- | -- | 20 | 23 | 20 | 23 |
|  | **Total identified** | **1,278** | **1,178** | **11,870** | **10,845** | **13,148** | **12,023** |
|  | **Unidentified** | **734** | **733** | **518** | **527** | **1,252** | **1,260** |
|  | **Grand total** | **2,012** | **1,911** | **12,388** | **11,372** | **14,400** | **13,283** |

W Withheld to avoid disclosing company proprietary data; included with "Unidentified."

[1] Does not include elemental sulfur used for production of sulfuric acid.

[2] No elemental sulfur used in inorganic pigments.

[3] Includes elemental sulfur used in cellulosic fibers.

[4] Included with "Synthetic rubber and other plastic materials and synthetics."

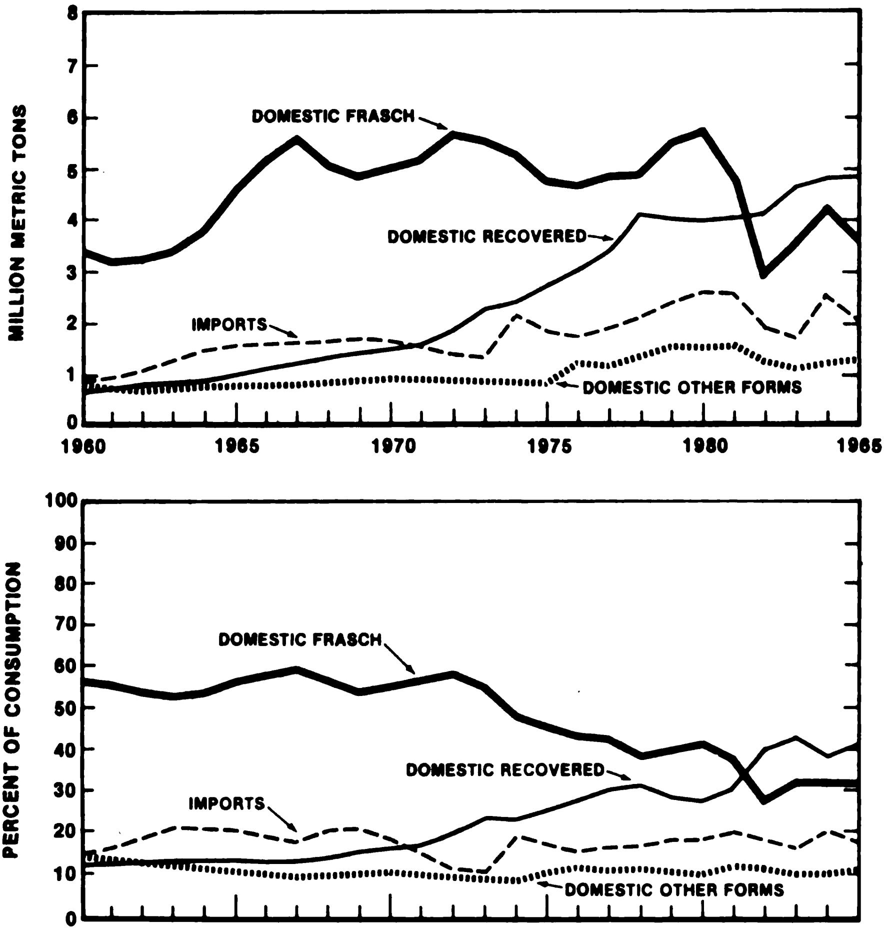

Figure 3.—Trends in the consumption of sulfur in the United States.

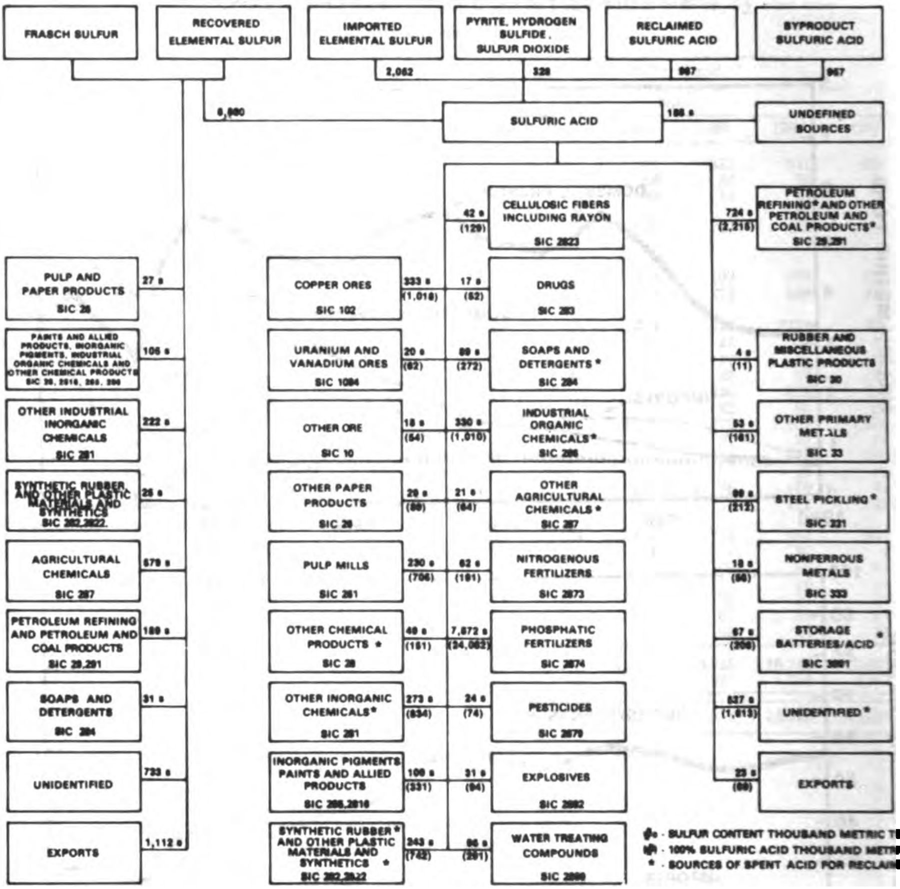
FRASCH SULFUR
RECOVERED ELEMENTAL SULFUR
IMPORTED ELEMENTAL SULFUR
PYRITE, HYDROGEN SULFIDE, SULFUR DIOXIDE
RECLAIMED SULFURIC ACID
BYPRODUCT SULFURIC ACID
2,062
328
987
967
6,980
SULFURIC ACID
188 s
UNDEFINED SOURCES
PULP AND PAPER PRODUCTS SIC 26
27 s
PAINTS AND ALLIED PRODUCTS, INORGANIC PIGMENTS, INDUSTRIAL ORGANIC CHEMICALS AND OTHER CHEMICAL PRODUCTS SIC 28, 2816, 285, 286
106 s
OTHER INDUSTRIAL INORGANIC CHEMICALS SIC 281
222 s
SYNTHETIC RUBBER, AND OTHER PLASTIC MATERIALS AND SYNTHETICS SIC 282,2822
26 s
AGRICULTURAL CHEMICALS SIC 287
579 s
PETROLEUM REFINING AND PETROLEUM AND COAL PRODUCTS SIC 29,291
189 s
SOAPS AND DETERGENTS SIC 284
31 s
UNIDENTIFIED
733 s
EXPORTS
1,112 s
COPPER ORES SIC 102
333 s (1,018)
URANIUM AND VANADIUM ORES SIC 1094
20 s (62)
OTHER ORE SIC 10
18 s (54)
OTHER PAPER PRODUCTS SIC 26
29 s (89)
PULP MILLS SIC 261
230 s (706)
OTHER CHEMICAL PRODUCTS * SIC 28
49 s (151)
OTHER INORGANIC CHEMICALS* SIC 281
273 s (834)
INORGANIC PIGMENTS PAINTS AND ALLIED PRODUCTS SIC 285,2816
108 s (331)
SYNTHETIC RUBBER* AND OTHER PLASTIC MATERIALS AND SYNTHETICS * SIC 282,2822
243 s (742)
42 s (129)
CELLULOSIC FIBERS INCLUDING RAYON SIC 2823
17 s (52)
DRUGS SIC 283
89 s (272)
SOAPS AND DETERGENTS * SIC 284
330 s (1,010)
INDUSTRIAL ORGANIC CHEMICALS* SIC 286
21 s (64)
OTHER AGRICULTURAL CHEMICALS * SIC 287
62 s (191)
NITROGENOUS FERTILIZERS SIC 2873
7,872 s (24,082)
PHOSPHATIC FERTILIZERS SIC 2874
24 s (74)
PESTICIDES SIC 2879
31 s (94)
EXPLOSIVES SIC 2892
96 s (291)
WATER TREATING COMPOUNDS SIC 2899
724 s (2,218)
PETROLEUM REFINING* AND OTHER PETROLEUM AND COAL PRODUCTS* SIC 29,291
4 s (11)
RUBBER AND MISCELLANEOUS PLASTIC PRODUCTS SIC 30
53 s (161)
OTHER PRIMARY METALS SIC 33
69 s (212)
STEEL PICKLING* SIC 331
18 s (56)
NONFERROUS METALS SIC 333
67 s (206)
STORAGE BATTERIES/ACID * SIC 3691
527 s (1,613)
UNIDENTIFIED*
23 s (69)
EXPORTS
#s - SULFUR CONTENT THOUSAND METRIC T
(#) - 100% SULFURIC ACID THOUSAND METRIC
* - SOURCES OF SPENT ACID FOR RECLA

Figure 4.—Sulfur-sulfuric acid supply and end-use relationship in 1985.

## STOCKS

An increase in inventories held by Frasch producers occurred primarily during the last quarter of the year when sulfur demand by the fertilizer industry decreased. Combined yearend stocks amounted to approximately a 3-1/2-month supply compared with a 2-1/2-month supply in 1984, based on domestic and export demands for Frasch and recovered sulfur.

### Table 13.—Yearend sulfur stocks of U.S. producers

(Thousand metric tons)

| Year | Frasch | Recovered | Total |
|---|---|---|---|
| 1981 | ʳ3,354 | 192 | ʳ3,546 |
| 1982 | ʳ3,980 | 238 | ʳ4,218 |
| 1983 | ʳ3,070 | 153 | ʳ3,223 |
| 1984 | ʳ2,264 | 155 | ʳ2,419 |
| 1985 | 2,598 | 201 | 2,799 |

ʳRevised.

## PRICES

The posted price for liquid sulfur, exterminal Tampa, FL, was unchanged during 1985 at $157.50 per long ton; price discounts, which had begun in 1983 for large-volume customers, of $10 per long ton remained in effect. Spot prices for sulfur, f.o.b. Vancouver, British Columbia, Canada, were $140 to $152 per metric ton during the first half of the year but decreased slowly to the Vancouver contract price of $135 per metric ton by yearend.

On the basis of total shipments and value reported to the Bureau of Mines, the average value of shipments of Frasch sulfur, f.o.b. mine, for domestic consumption and exports combined increased. The average value, f.o.b. plant, for shipments of recovered elemental sulfur varied widely by geographic region as follows: lowest in the Rocky Mountain States, higher on the west coast, somewhat higher in the midcontinent, and near the values for Frasch sulfur in the East and South. Although reported values for recovered elemental sulfur were generally higher throughout the Nation, the disproportionately low value for Wyoming distorts the average value calculation for all recovered elemental shipments.

**Table 14.—Reported sales values of shipments of sulfur, f.o.b. mine or plant**

(Dollars per metric ton)

| Year | Frasch | Recovered | Average |
|---|---|---|---|
| 1981 | 121.11 | 97.97 | 111.48 |
| 1982 | 120.79 | 97.89 | 108.27 |
| 1983 | 100.76 | 76.22 | 87.24 |
| 1984 | 109.20 | 80.02 | 94.31 |
| 1985 | 122.62 | 92.11 | 106.46 |

## FOREIGN TRADE

Exports of elemental sulfur from the United States, including the Virgin Islands, were about the same as those of 1984 in quantity but increased 21% in value. According to the Bureau of the Census, exports from the west coast increased by nearly 70,000 tons in 1985 to 318,000 tons, or 23% of total U.S. exports.

The United States continued to be a net sulfur importer with imports exceeding exports by over 700,000 tons. Frasch sulfur from Mexico and recovered elemental sulfur from Canada, both delivered to U.S. terminals and consumers in the liquid phase, continued to furnish nearly all U.S. sulfur import requirements. Total elemental sulfur imports decreased 18% in quantity; the average value for the imports, however, increased substantially so that the total value of imports was essentially unchanged from that of 1984.

The United States also had significant trade in sulfuric acid. Sulfuric acid exports increased slightly in terms of quantity, but total value was essentially unchanged from that of 1984. Imports were mostly from Canada; the quantity increased slightly, while the value was lower than in 1984.

**Table 15.—U.S. exports[1] of elemental sulfur, by country**

(Thousand metric tons and thousand dollars)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| Argentina | 1 | 512 | 31 | 3,216 |
| Belgium-Luxembourg | 397 | 46,983 | 394 | 48,678 |
| Brazil | 205 | 23,903 | 173 | 26,617 |
| Canada | 2 | 124 | 5 | 270 |
| Chile | 3 | 532 | 8 | 1,236 |
| Colombia | (2) | 263 | 17 | 2,591 |
| Egypt | 132 | 17,535 | 28 | 4,693 |
| France | 20 | 1,913 | 26 | 3,577 |
| India | 127 | 14,334 | 76 | 11,130 |
| Indonesia | 18 | 2,278 | (2) | 1 |
| Israel | -- | -- | 37 | 4,994 |
| Italy | 16 | 1,470 | 22 | 3,128 |
| Mexico | 54 | 2,955 | 97 | 9,799 |
| Morocco | 162 | 21,973 | 220 | 35,074 |
| Netherlands | 13 | 1,399 | 6 | 772 |

See footnotes at end of table.

## Table 15.—U.S. exports[1] of elemental sulfur, by country —Continued

(Thousand metric tons and thousand dollars)

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value |
| Philippines | 5 | 588 | 11 | 1,594 |
| Romania | 21 | 2,400 | 24 | 2,658 |
| Senegal | 11 | 909 | -- | -- |
| Spain | ([2]) | 10 | 15 | 2,288 |
| Taiwan | 43 | 4,566 | 23 | 2,883 |
| Tunisia | 40 | 1,918 | 83 | 11,856 |
| Turkey | 21 | 2,383 | 24 | 8,388 |
| Uruguay | 10 | 980 | 3 | 465 |
| Venezuela | 1 | 179 | 14 | 2,290 |
| Yugoslavia | 16 | 1,963 | 15 | 1,944 |
| Other | [r]15 | [r]3,996 | 14 | 4,104 |
| Total[3] | 1,834 | 156,067 | 1,365 | 189,248 |

[r] Revised.

[1] Includes exports from the Virgin Islands.

[2] Less than 1/2 unit.

[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## Table 16.—U.S. exports of sulfuric acid (100% $H_2SO_4$), by country

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Brazil | 26,831 | $1,012 | 28,397 | $982 |
| Canada | 33,798 | 1,510 | 15,258 | 708 |
| Chile | 10,355 | 343 | 4,099 | 177 |
| Dominican Republic | 2,966 | 299 | 2,729 | 227 |
| Ecuador | 6,198 | 330 | 2,083 | 97 |
| France | 1,424 | 50 | 242 | 11 |
| Guyana | 1,539 | 224 | 2 | 4 |
| Jamaica | 1,665 | 114 | 172 | 17 |
| Korea, Republic of | 658 | 399 | 1,388 | 716 |
| Mexico | 6,815 | 293 | 16,699 | 742 |
| Netherlands | 32 | 4 | 2 | 2 |
| Netherlands Antilles | 6,295 | 331 | 4,357 | 213 |
| Panama | 2,500 | 126 | 2,368 | 121 |
| Saudi Arabia | 1,239 | 252 | 659 | 32 |
| Switzerland | -- | -- | 8,198 | 300 |
| Trinidad and Tobago | 2,379 | 136 | 1,561 | 65 |
| Venezuela | 6,182 | 308 | 31,960 | 1,367 |
| Other | 8,441 | 1,042 | 5,146 | 863 |
| Total | 119,317 | 6,773 | [1]125,320 | [1] [2]6,645 |

[1] Excludes 900 tons valued at $3,662,856 to Morocco not believed to be sulfuric acid.

[2] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

## Table 17.—U.S. imports of elemental sulfur, by country

(Thousand metric tons and thousand dollars)

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity | Value[1] | Quantity | Value[1] |
| Canada | 1,812 | 117,776 | 1,354 | 110,231 |
| Mexico | 722 | 79,756 | 724 | 85,778 |
| Venezuela | 22 | 2,531 | 24 | 2,972 |
| Other[2] | 1 | 126 | 2 | 259 |
| Total | 2,557 | 200,189 | 2,104 | 199,240 |

[1] Declared customs valuation.

[2] Includes Belgium, China, the Federal Republic of Germany, Italy, Japan, and Netherlands Antilles in 1984 and China, the Federal Republic of Germany, Italy, Japan, New Caledonia, and the United Kingdom in 1985.

Source: Bureau of the Census.

Table 18.—U.S. imports of sulfuric acid (100% $H_2SO_4$), by country

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Quantity (metric tons) | Value[1] (thousands) | Quantity (metric tons) | Value[1] (thousands) |
| Belgium | -- | -- | 38 | $46 |
| Canada | 356,484 | $15,175 | 426,909 | 17,871 |
| France | (2) | 2 | 23 | 28 |
| Germany, Federal Republic of | 13,672 | 929 | 46 | 30 |
| Mexico | 15,105 | 784 | -- | -- |
| Netherlands | -- | -- | 4,475 | 429 |
| Norway | 6,464 | 568 | -- | -- |
| Spain | 18,468 | 1,323 | 9,560 | 611 |
| Switzerland | 15,513 | 595 | -- | -- |
| Other | [r]3 | [r]16 | 4 | 23 |
| Total | 425,709 | [3]19,391 | 441,055 | 19,038 |

[r] Revised.

[1] Declared c.i.f. valuation.

[2] Less than 1/2 unit.

[3] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

World production increased for the second consecutive year as recovery continued from the depressed levels of 1982 and 1983. Elemental sulfur production increased by nearly 2 million tons, and sulfur production in all forms approached the record-high level of 1980. Nevertheless, continued world sulfur demand in excess of production in 1985 required stock withdrawals of nearly 2 million tons, which was substantially less than had been required during each of the previous 2 years.

International trade in elemental sulfur decreased by more than 1 million tons to about 16 million tons. Canada continued as the world's leading exporter, followed, in descending order of quantity, by Poland, the United States, Saudi Arabia, Mexico, the Federal Republic of Germany, and France. The United States was again the leading importer. Other nations that imported significant quantities of sulfur, in decreasing order of quantity, were Morocco, the U.S.S.R., Brazil, India, the United Kingdom, and Tunisia.

International sulfur prices remained high for most of the year with a moderate increase in price for contract tonnage instituted at midyear. Spot prices, which were about $150 per ton, f.o.b. Vancouver, British Columbia, Canada, and Persian Gulf ports for much of the year, declined in the final 4 months to approach the contract price of $135 to $140 per ton. The spot-price decline was attributed to a weakening of demand and the decision by buyers for India to reduce reliance on spot sales and enter into long-term contracts with several major sulfur suppliers.

**Canada.**—Shipments of sulfur in all forms were about 8.66 million tons, or 1.9 million tons greater than output, but 7% less than 1984 shipments. Exports decreased slightly to 7.54 million tons. Although exports through the Port of Vancouver, British Columbia, increased to a record-high volume of 6.14 million tons, exports to the United States fell about 500,000 tons to 1.35 million tons. Canadian sulfur stocks in block located in Alberta Province and awaiting shipment at Vancouver declined to less than 10 million tons. Canadian block inventory, which had exceeded 21 million tons in 1978, had for many years been regarded by the industry as a buffer to accommodate changes in world demand and to provide a reasonably stable price environment. The fall in stocks through the 10-million-ton level signaled the world sulfur industry that this huge inventory was transitory and that a search for new economic sources of elemental sulfur should be undertaken.

**Iran.**—Sulfur production remained substantially less than capacity because of the ongoing war with neighboring Iraq. Some sulfur exports were transferred overland to a port east of the Strait of Hormuz that was beyond Iraqi aircraft range.

**Iraq.**—Sulfur exports continued to be routed overland through neighboring countries because safe passage could not be assured for Iraqi material in the Persian Gulf. Production remained relatively unchanged and well below capacity at natural gas plants and the Mishraq Frasch mine.

**Mexico.**—Increased Frasch sulfur output reflected efforts to bring the Patapa Mine up to its design capacity of 350,000 tons per year. Production also increased at Coachapa in the Salinas Basin. Engineering work to supply air, steam, and hot water to the Otapan deposit was well under way. Sulfur production from Otapan was planned to begin in 1986. Mexican sulfur exports continued to decline because of growing domestic demand. Solid sulfur was imported from Canada and the United States because of difficulties in transporting sulfur to the Lázaro Cárdenas fertilizer facility on the Pacific coast from the mining areas near the gulf coast.

**Poland.**—Frasch sulfur production declined because of severe winter weather, and in February, a force majeure declared that contract tonnages would be decreased by 8% during 1985. Sulfur exports decreased nearly 200,000 tons to 3.9 million tons. Of this, 1.9 million tons was exported to Eastern Europe, and 1.1 million tons, to Western Europe; most of the remainder was shipped to Brazil, Morocco, and Tunisia.

**Saudi Arabia.**—Sulfur production increased despite the low level of petroleum production because of increased output of nonassociated gas. Production of sulfur excess to exports and internal consumption caused stocks to increase by nearly 200,000 tons. Sulfur exports declined nearly 600,000 tons to slightly over 900,000 tons.

The Fletcher-process prilling plant was operated by the Saudi Sulfur Co. adjacent to the Berri natural gas plant. In December, the General Petroleum and Mineral Organization, a Government agency and owner of the nation's sulfur facilities, contracted with Saudi Sulfur's parent company, Devco International of the United States, to build a new three-unit Fletcher-process prilling plant at Jubail to replace the plant destroyed by fire in 1984. Plans were for Saudi Sulfur to continue operating the plant at Berri until the new facility was completed.

**U.S.S.R.**—In April, a French consortium led by Lurgi S.A. won a $135 million contract to supply the process plant of the Tengiz oil and gas project in Kazakhstan northeast of the Aral Sea. Tengiz associated gas contains about 16% $H_2S$ and 5% carbon dioxide. The plant was designed to process the 1.5-billion-cubic-meter-per-day gas output and recover 1,600 tons per day of sulfur along with ethane, butane, and other condensates.[2] In June, the Tengiz Field's development was complicated by a major blowout and fire. The fiery plume, about 200 meters high, was reportedly visible 90 miles away.[3] Extinguishing the fire was complicated by the high $H_2S$ concentration of the associated gas and the 12,000-pound-per-square-inch formation pressure. The fire was reportedly still burning at yearend.

Technip of France was awarded a contract to install the second stage of the Astrakhan gas-processing complex in the Volga River Delta north of the Caspian Sea. Astrakhan II was designed to process up to 6.9 billion cubic meters per year of gas in four trains and to recover 2.7 million tons per year of sulfur from the gas, which contained about 16% $H_2S$. These design capacities were similar to those of stage 1. Contracts for stage 1 had been awarded in 1983 to Creusot-Loire Entreprise of France and Mannesmann AG of the Federal Republic of Germany.[4] The two-phase complex was planned to be the largest sulfur-producing facility in the world.

## Table 19.—Sulfur: World production in all forms, by country and source[1]

(Thousand metric tons)

| Country[2] and source[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria: Byproduct, petroleum and natural gas[e] | 15 | 10 | 15 | 20 | 20 |
| Argentina:[e] | | | | | |
| Native (from caliche) | 10 | -- | -- | (4) | -- |
| Byproduct, all sources | NA | -- | -- | (4) | -- |
| Total | 10 | -- | -- | (4) | -- |
| Australia: | | | | | |
| Byproduct: | | | | | |
| Metallurgy | [r]142 | [r]146 | 170 | 190 | 190 |
| Petroleum | 14 | 17 | 13 | 13 | [5]13 |
| Total | [r]156 | [r]163 | 183 | 203 | 203 |
| Austria: | | | | | |
| Byproduct: | | | | | |
| Metallurgy | 9 | 10 | 9 | 10 | 10 |
| Petroleum and natural gas | 28 | 38 | 32 | 28 | 25 |
| Gypsum | 25 | 27 | 26 | 26 | 26 |
| Total | 62 | 75 | 67 | 64 | 61 |
| Bahamas: Byproduct, petroleum[e] | 5 | 5 | 5 | [r]3 | 2 |
| Bahrain: Byproduct, petroleum | [e]36 | 34 | 49 | [e]50 | 50 |
| Belgium: Byproduct, all sources[e] | 270 | 270 | 250 | 240 | 240 |
| Bolivia: Native | 10 | 6 | 3 | 2 | 2 |
| Brazil: | | | | | |
| Frasch | -- | -- | 1 | [e]1 | 2 |
| Pyrites | 44 | 54 | 55 | [e]55 | 60 |
| Byproduct: | | | | | |
| Metallurgy | 17 | 30 | 150 | [e]150 | 150 |
| Petroleum | 102 | 100 | 110 | [e]110 | 125 |
| Total | 163 | 184 | 316 | [e]316 | 337 |
| Bulgaria:[e] | | | | | |
| Pyrites | [r]300 | [r]300 | [r]300 | [r]300 | 300 |
| Byproduct, all sources | 70 | 70 | 70 | 70 | 70 |
| Total | [r]370 | [r]370 | [r]370 | [r]370 | 370 |
| Canada: | | | | | |
| Pyrites[e] [6] | 10 | [r]8 | [r]9 | [r]10 | 10 |
| Byproduct: | | | | | |
| Metallurgy | 783 | 627 | 678 | [e]875 | 900 |
| Natural gas | 5,599 | 5,226 | 5,390 | 5,260 | [5]5,296 |
| Petroleum[e] | 160 | 160 | 170 | 165 | 150 |
| Tar sands | 247 | 259 | 330 | 296 | [5]392 |
| Total | 6,799 | [r]6,280 | 6,577 | 6,606 | 6,748 |
| Chile: | | | | | |
| Native: | | | | | |
| Refined | 5 | 7 | 16 | 14 | [5]15 |
| From caliche | 110 | 98 | 83 | 40 | [5]64 |
| Byproduct, metallurgy | 28 | 32 | 32 | 32 | [5]30 |
| Total | 143 | 137 | 131 | 86 | [5]109 |
| *China:*[e] | | | | | |
| Native | 200 | 200 | 200 | 200 | 300 |
| Pyrites | 1,800 | 1,800 | 2,300 | 2,100 | 2,200 |
| Byproduct, all sources | 300 | 300 | 350 | 350 | 400 |
| Total | 2,300 | 2,300 | 2,850 | 2,650 | 2,900 |
| Colombia: | | | | | |
| Native | 26 | 33 | 31 | 36 | 35 |
| Byproduct, petroleum | 2 | 2 | [e]3 | [e]3 | 3 |
| Total | 28 | 35 | 34 | 39 | 38 |
| Cuba:[e] | | | | | |
| Pyrites | 14 | 20 | [r]5 | (4) | -- |
| Byproduct, petroleum | 8 | 8 | 8 | 8 | 8 |
| Total | 22 | 28 | [r]13 | [r]8 | 8 |
| *Cyprus:*[7] Pyrites | 9 | [e]26 | 21 | [e]20 | 20 |

See footnotes at end of table.

## Table 19.—Sulfur: World production in all forms, by country and source[1] —Continued

(Thousand metric tons)

| Country[2] and source[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Czechoslovakia:[e] | | | | | |
| Native | 5 | 5 | 5 | 5 | 6 |
| Pyrites | 60 | 60 | 60 | 60 | 62 |
| Byproduct, all sources | 10 | 10 | 10 | 10 | 12 |
| Total | 75 | 75 | 75 | 75 | 80 |
| Denmark: Byproduct, petroleum | 6 | 7 | [r] [e]9 | 11 | 7 |
| Ecuador:[e] | | | | | |
| Native | 2 | 5 | 5 | 5 | 4 |
| Byproduct: | | | | | |
| Natural gas | 5 | 5 | 5 | 5 | 5 |
| Petroleum | 5 | 5 | 5 | 5 | 5 |
| Total | 12 | 15 | 15 | 15 | 14 |
| Egypt: Byproduct, petroleum and natural gas | 2 | 2 | 1 | [e]2 | 2 |
| Finland: | | | | | |
| Pyrites | 184 | 177 | 224 | 211 | 210 |
| Byproduct: | | | | | |
| Metallurgy | [r]268 | 270 | 264 | 265 | 260 |
| Petroleum | 45 | 40 | 48 | 45 | 45 |
| Total | [r]497 | [r]487 | 536 | 521 | 515 |
| France: | | | | | |
| Byproduct: | | | | | |
| Natural gas | 1,701 | [r]1,690 | 1,653 | 1,589 | 1,424 |
| Petroleum | 221 | 235 | 157 | 163 | 160 |
| Unspecified[e] | 120 | 110 | [r]100 | 110 | 110 |
| Total | 2,042 | [r]2,035 | 1,910 | 1,862 | 1,694 |
| German Democratic Republic:[e] | | | | | |
| Pyrites | 10 | -- | -- | -- | -- |
| Byproduct, all sources | 350 | 360 | 360 | 350 | 330 |
| Total | 360 | 360 | 360 | 350 | 330 |
| Germany, Federal Republic of: | | | | | |
| Pyrites | 213 | 229 | -- | -- | -- |
| Byproduct: | | | | | |
| Metallurgy[e] [6] | 400 | 400 | 400 | 350 | 320 |
| Natural gas | 834 | 872 | 632 | [r] [e]900 | 1,000 |
| Petroleum[e] | 190 | 220 | 195 | 190 | 200 |
| Unspecified[e] | 95 | 100 | 95 | 90 | 85 |
| Total[e] | 1,732 | 1,821 | 1,322 | [r]1,530 | 1,605 |
| Greece: | | | | | |
| Pyrites | 76 | 55 | 67 | 78 | 78 |
| Byproduct: | | | | | |
| Natural gas | 4 | 97 | [e]115 | [e]120 | 120 |
| Petroleum | 7 | 8 | 5 | [e]5 | 5 |
| Total | 87 | 160 | [r] [e]187 | [r] [e]203 | 203 |
| Hungary:[e] | | | | | |
| Pyrites | 3 | 3 | 3 | 2 | 2 |
| Byproduct, all sources | 9 | 9 | 9 | 9 | 9 |
| Total | 12 | 12 | 12 | 11 | 11 |
| India: | | | | | |
| Pyrites | 23 | 22 | 25 | 18 | 20 |
| Byproduct: | | | | | |
| Metallurgy[e] | 92 | 100 | 110 | 115 | 120 |
| Petroleum | 4 | 5 | 4 | [e]5 | 5 |
| Total[e] | 119 | 127 | 139 | [r]138 | 145 |
| Indonesia:[7] Native | 1 | 1 | 3 | 6 | 5 |
| Iran:[e] | | | | | |
| Native | 50 | 10 | 20 | 30 | 30 |
| Byproduct, petroleum and natural gas | 6 | 10 | 25 | 30 | 180 |
| Total | 56 | 20 | 45 | 60 | 210 |

See footnotes at end of table.

### Table 19.—Sulfur: World production in all forms, by country and source[1] —Continued

(Thousand metric tons)

| Country[2] and source[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Iraq:[e] | | | | | |
| Frasch | [5]200 | 300 | 300 | 500 | 500 |
| Byproduct, petroleum and natural gas | [5]40 | 40 | 40 | 70 | 70 |
| Total | [5]240 | 340 | 340 | 570 | 570 |
| Ireland: Pyrites[e] | 11 | [r]6 | (4) | (4) | -- |
| Israel: Byproduct, petroleum and natural gas[e] | 10 | 10 | 10 | 10 | 10 |
| Italy: | | | | | |
| Native | 20 | 10 | 9 | 8 | [5]1 |
| Pyrites | 261 | 269 | 271 | 192 | [5]280 |
| Byproduct, all sources[e] [9] | 230 | 210 | 210 | 200 | 200 |
| Total[e] | 511 | 489 | [r]490 | [r]400 | 481 |
| Japan: | | | | | |
| Pyrites | 293 | 276 | 272 | 259 | [5]253 |
| Byproduct: | | | | | |
| Metallurgy | 1,236 | 1,268 | 1,239 | 1,191 | 1,192 |
| Petroleum | 1,080 | 1,051 | 1,102 | 1,142 | 1,065 |
| Total | 2,609 | 2,595 | 2,613 | 2,592 | 2,510 |
| Korea, North:[e] | | | | | |
| Pyrites | 225 | 200 | 200 | 200 | 200 |
| Byproduct, metallurgy | 30 | 30 | 30 | 30 | 30 |
| Total | 255 | 230 | 230 | 230 | 230 |
| Korea, Republic of: | | | | | |
| Pyrites | -- | -- | (10) | (10) | NA |
| Byproduct:[e] | | | | | |
| Metallurgy | 54 | 54 | 54 | 54 | 55 |
| Petroleum | 36 | 36 | 36 | 36 | 35 |
| Total[e] | 90 | 90 | 90 | 90 | 90 |
| Kuwait: Byproduct, petroleum and natural gas | 97 | 141 | 145 | 151 | [5]198 |
| Libya: Byproduct, petroleum and natural gas[e] | 16 | 20 | 20 | 20 | 16 |
| Mexico: | | | | | |
| Frasch | 1,652 | 1,391 | 1,225 | 1,364 | 1,555 |
| Byproduct: | | | | | |
| Metallurgy[e] | 100 | 100 | 100 | [r]160 | 160 |
| Petroleum and natural gas | 426 | 425 | 377 | 461 | [5]475 |
| Total[e] | 2,178 | 1,916 | 1,702 | [r]1,985 | 2,190 |
| Morocco: Pyrites | 22 | -- | -- | -- | -- |
| Namibia: Pyrites | 8 | 58 | 81 | 104 | 100 |
| Netherlands:[e] | | | | | |
| Byproduct: | | | | | |
| Metallurgy | 90 | 100 | 100 | 90 | 85 |
| Petroleum | 55 | 65 | 105 | 105 | 95 |
| Total | 145 | 165 | 205 | 195 | 180 |
| Netherlands Antilles: Byproduct, petroleum | [e]90 | [e]90 | 87 | 63 | 25 |
| New Zealand: Byproduct, all sources | (10) | (10) | 1 | 1 | 1 |
| Norway: | | | | | |
| Pyrites | [r]218 | [r]213 | 179 | 209 | 210 |
| Byproduct: | | | | | |
| Metallurgy[e] | [r]37 | [r]83 | [r]95 | [r]58 | 60 |
| Petroleum | 8 | 8 | 8 | 8 | [5]8 |
| Total | 263 | 304 | 282 | 275 | [5]278 |
| Oman: Pyrites[e] | -- | -- | 11 | 31 | 31 |
| Pakistan: | | | | | |
| Native | (10) | 1 | 1 | 1 | 1 |
| Byproduct, all sources[e] | 14 | 19 | 26 | 26 | 26 |
| Total | 14 | 20 | 27 | 27 | 27 |
| Peru: | | | | | |
| Native | (10) | (10) | (10) | (10) | (10) |
| Byproduct, all sources[e] | 20 | 58 | 65 | 70 | 70 |
| Total | 20 | 58 | 65 | 70 | 70 |

See footnotes at end of table.

## Table 19.—Sulfur: World production in all forms, by country and source[1] —Continued

(Thousand metric tons)

| Country[2] and source[3] | 1981 | 1982 | 1983 | 1984$^{p}$ | 1985$^{e}$ |
|---|---|---|---|---|---|
| Philippines: | | | | | |
| Pyrites | 46 | 30 | 29 | 35 | 107 |
| Byproduct, metallurgy | -- | -- | 57 | 95 | 100 |
| Total | 46 | 30 | 86 | 130 | 207 |
| Poland:$^{e}$ [11] | | | | | |
| Frasch | 4,295 | $^{r}$4,428 | $^{r}$4,460 | 4,500 | 4,386 |
| Native | 478 | $^{r}$492 | 500 | $^{r}$490 | 490 |
| Byproduct: | | | | | |
| Metallurgy[12] | $^{r}$180 | $^{r}$160 | $^{r}$170 | $^{r}$170 | 170 |
| Petroleum | 30 | 30 | 30 | 30 | 30 |
| Gypsum | 20 | 20 | 20 | 20 | 20 |
| Total | $^{r}$5,003 | $^{r}$5,130 | $^{r}$5,180 | $^{r}$5,210 | 5,096 |
| Portugal: | | | | | |
| Pyrites | $^{e}$135 | 116 | 124 | 140 | 145 |
| Byproduct, all sources | 2 | 2 | 5 | 4 | 5 |
| Total | 137 | 118 | 129 | 144 | 150 |
| Qatar: Byproduct, natural gas | 6 | 5 | 5 | 33 | 33 |
| Romania:$^{e}$ | | | | | |
| Pyrites | 300 | 200 | 200 | 200 | 200 |
| Byproduct, all sources | 150 | 150 | 150 | 150 | 150 |
| Total | 450 | 350 | 350 | 350 | 350 |
| Saudi Arabia: Byproduct, petroleum and natural gas$^{e}$ | 600 | 900 | 695 | [5]833 | 1,100 |
| Singapore: Byproduct, petroleum | (10) | 15 | 4 | 6 | 5 |
| South Africa, Republic of: | | | | | |
| Pyrites | 502 | 465 | 474 | 464 | [5]474 |
| Byproduct:$^{e}$ | | | | | |
| Metallurgy | 100 | 135 | 125 | [5]91 | [5]85 |
| Petroleum | 27 | 25 | 32 | 30 | 35 |
| Total | 629 | 625 | 631 | 585 | 594 |
| Spain: | | | | | |
| Pyrites | 1,118 | 1,029 | 1,073 | 1,094 | [5]1,133 |
| Byproduct: | | | | | |
| Coal (lignite) gasification$^{e}$ | 3 | 3 | 3 | 3 | 2 |
| Metallurgy | 135 | $^{e}$125 | $^{e}$120 | 125 | 115 |
| Petroleum$^{e}$ | [5]12 | 10 | 8 | $^{r}$9 | 9 |
| Total$^{e}$ | 1,268 | 1,167 | 1,204 | $^{r}$1,231 | 1,259 |
| Sweden: | | | | | |
| Pyrites | 202 | 204 | 208 | $^{r}$ $^{e}$230 | 225 |
| Byproduct: | | | | | |
| Metallurgy$^{e}$ | $^{r}$99 | $^{r}$111 | $^{r}$125 | $^{r}$132 | 130 |
| Petroleum | 37 | 22 | 20 | 25 | 25 |
| Unspecified | (4) | (4) | (4) | (4) | -- |
| Total | $^{r}$338 | $^{r}$337 | 353 | 387 | 380 |
| Switzerland: Byproduct, all sources | 3 | 3 | 3 | 3 | 3 |
| Syria: Byproduct, petroleum and natural gas | 6 | 22 | $^{e}$30 | $^{e}$35 | 35 |
| Taiwan: | | | | | |
| Pyrites | (10) | -- | -- | -- | -- |
| Byproduct, all sources | 10 | 20 | 27 | 29 | [5]43 |
| Total | 10 | 20 | 27 | 29 | [5]43 |
| Trinidad and Tobago: Byproduct, petroleum | 44 | 13 | $^{e}$8 | $^{e}$7 | 5 |
| Turkey: | | | | | |
| Native | $^{r}$29 | $^{e}$32 | 35 | 41 | 45 |
| Pyrites$^{e}$ | 29 | $^{r}$2 | $^{r}$2 | (4) | -- |
| Byproduct, all sources$^{e}$ | $^{r}$73 | $^{r}$75 | $^{r}$75 | $^{r}$78 | 80 |
| Total$^{e}$ | $^{r}$131 | $^{r}$109 | $^{r}$112 | $^{r}$119 | 125 |
| U.S.S.R.:$^{e}$ | | | | | |
| Frasch | 800 | 800 | 800 | 800 | 850 |
| Native | 2,000 | 1,900 | 1,800 | 1,800 | 1,700 |
| Pyrites | 3,600 | 3,500 | 3,400 | $^{r}$3,400 | 3,350 |

See footnotes at end of table.

## Table 19.—Sulfur: World production in all forms, by country and source[1] —Continued

(Thousand metric tons)

| Country[2] and source[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| U.S.S.R.[e] —Continued | | | | | |
| Byproduct: | | | | | |
| Coal | (4) | (4) | (4) | (4) | -- |
| Metallurgy | [r]425 | [r]425 | [r]450 | [r]450 | 475 |
| Natural gas | [r]2,650 | [r]2,700 | [r]2,750 | [r]2,800 | 2,900 |
| Petroleum | [r]425 | [r]425 | [r]450 | [r]450 | 450 |
| Total | [r]9,900 | [r]9,750 | [r]9,650 | [r]9,700 | 9,725 |
| United Arab Emirates: Abu Dhabi: | | | | | |
| Byproduct: | | | | | |
| Natural gas | -- | -- | -- | -- | 277 |
| Petroleum | -- | [e]5 | 10 | 15 | 15 |
| Total | -- | [e]5 | 10 | 15 | 292 |
| United Kingdom: | | | | | |
| Byproduct: | | | | | |
| Metallurgy | 55 | 61 | 69 | 71 | 70 |
| Petroleum | 75 | 59 | 55 | 75 | 80 |
| Spent oxides | 4 | [r]3 | 3 | 1 | 1 |
| Total | 134 | 123 | 127 | 147 | 151 |
| United States: | | | | | |
| Frasch | 6,348 | 4,210 | 3,202 | 4,193 | [5]5,011 |
| Pyrites | 307 | 265 | W | W | W |
| Byproduct: | | | | | |
| Metallurgy | 1,159 | 828 | 831 | 962 | [5]957 |
| Natural gas | 1,971 | 1,960 | 2,371 | 2,407 | [5]2,373 |
| Petroleum | 2,288 | 2,444 | 2,584 | 2,807 | [5]2,940 |
| Unspecified | 72 | 80 | 302 | 283 | [5]328 |
| Total | 12,145 | 9,787 | 9,290 | 10,652 | [5]11,609 |
| Uruguay: Byproduct, petroleum[e] | 2 | 2 | 2 | 2 | 2 |
| Venezuela: Byproduct, petroleum and natural gas[e] | 85 | 85 | 85 | 86 | 88 |
| Yugoslavia: | | | | | |
| Pyrites and pyrrhotite | [r]286 | [r]353 | 298 | 301 | [5]323 |
| Byproduct:[e] | | | | | |
| Metallurgy | 200 | 200 | 180 | 160 | 170 |
| Petroleum | 4 | 4 | 3 | 3 | 3 |
| Total[e] | [r]490 | [r]557 | [r]481 | [r]464 | 496 |
| Zaire: Byproduct, metallurgy[e] | 25 | 25 | 36 | [r]37 | 36 |
| Zambia: | | | | | |
| Pyrites | (10) | 1 | 25 | 18 | 25 |
| Byproduct, all sources | 90 | 84 | [e]80 | [e]80 | 80 |
| Total | 90 | 85 | 105 | [r] [e]98 | 105 |
| Zimbabwe: | | | | | |
| Pyrites | 25 | 25 | 25 | [e]25 | 26 |
| Byproduct, all sources[e] | 5 | 5 | 5 | 5 | 5 |
| Total | 30 | 30 | 30 | 30 | 31 |

See footnotes at end of table.

## Table 19.—Sulfur: World production in all forms, by country and source[1] —Continued

(Thousand metric tons)

| Country[2] and source[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Grand total | [r]53,550 | [r]50,870 | 50,530 | 52,697 | 54,856 |
| Of which: | | | | | |
| Frasch | 13,295 | [r]11,129 | 9,988 | 11,358 | 12,304 |
| Native | [r]2,946 | [r]2,800 | 2,711 | 2,677 | 2,696 |
| Pyrites | [r]10,334 | [r]9,966 | 9,941 | 9,756 | 10,044 |
| Byproduct: | | | | | |
| Coal and coal gasification | [r]3 | [r]3 | 3 | 3 | 2 |
| Metallurgy | [r]5,664 | [r]5,320 | 5,594 | 5,863 | 5,870 |
| Natural gas | [r]12,770 | [r]12,555 | 12,921 | 13,114 | 13,428 |
| Petroleum | [r]5,018 | [r]5,150 | 5,325 | 5,580 | 5,806 |
| Petroleum and natural gas, undifferentiated | 1,331 | 1,703 | 1,475 | 1,746 | 2,219 |
| Spent oxides | 4 | [r]3 | 3 | 1 | 1 |
| Tar sands | 247 | 259 | 330 | 296 | 382 |
| Unspecified sources | [r]1,893 | [r]1,985 | 2,193 | 2,158 | 2,247 |
| Gypsum | 45 | 47 | 46 | 46 | 46 |

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; included with "Byproduct: Unspecified sources."

[1]Table includes data available through June 3, 1986.

[2]In addition to the countries listed, a number of nations may produce limited quantities of either elemental sulfur or compounds (chiefly $H_2S$ or $SO_2$) as a byproduct of petroleum, natural gas, and/or metallurgical operations, but output, if any, is not quantitatively reported, and no basis is available for the formulation of reliable estimates of output. Countries not listed in this table that may recover byproduct sulfur from oil refining include Albania, Bangladesh, Brunei, Burma, Costa Rica, Guatemala, Honduras, Jamaica, Malaysia, Nicaragua, Paraguay, and the People's Democratic Republic of Yemen. Albania and Burma may also produce byproduct sulfur from crude oil and natural gas extraction. No complete listing of other nations that may produce byproduct sulfur from metallurgical operations (including processing of coal for metallurgical use) can be compiled, but the total of such output is considered as small. Nations listed in this table that may have production from sources other than those listed are identified by individual footnotes.

[3]The term "source" reflects both the means of collecting sulfur and the type of raw material. Sources listed include the following: (1) Frasch recovery; (2) native, comprising all production of elemental sulfur by traditional mining methods (thereby excluding Frasch); (3) pyrites (whether or not the sulfur is recovered in the elemental form or as acid); (4) byproduct recovery, either as elemental sulfur or as sulfur compounds from coal gasification, metallurgical operations including associated coal processing, crude oil and natural gas extraction, petroleum refining, tar sand cleaning, and processing of spent oxide from stack-gas scrubbers; and (5) recovery from the processing of mined gypsum. Recovery of sulfur in the form of sulfuric acid from artificial gypsum produced as a byproduct of phosphatic fertilizer production is excluded because to include it would result in double counting. It should be noted that production of Frasch sulfur, other native sulfur, pyrites-derived sulfur, mined gypsum-derived sulfur, byproduct sulfur from extraction of crude oil and natural gas, and recovery from tar sands are all credited to the country of origin of the extracted raw material; in contrast, byproduct recovery from metallurgical operations, petroleum refineries, and spent oxides are credited to the nation where the recovery takes place, which in some instances is not the original source country of the crude product from which the sulfur is extracted.

[4]Revised to zero.

[5]Reported figure.

[6]Byproduct pyrite and pyrrhotite from the processing of metallic sulfide ores.

[7]In addition, may produce limited quantities of byproduct sulfur from oil refining.

[8]Includes only the elemental sulfur equivalent of sulfuric acid produced as a byproduct from metallurgical furnaces; additional output may be included under "Byproduct: Unspecified sources."

[9]Includes recovery from gypsum, if any.

[10]Less than 1/2 unit.

[11]Official Polish sources report total Frasch and native mined elemental sulfur output annually, undifferentiated; this figure has been divided between Frash and other native sulfur on the basis of information obtained from supplementary sources.

[12]Figures for Polish metallurgy byproduct sulfur have been revised from 1977-84. Revised figures not included in the table are, in thousand metric tons: 1977—235; 1978—225; 1979—210; and 1980—205.

## TECHNOLOGY

At the international conference Sulphur 85, 50 papers were presented on sulfur production, trade, forming, handling, acid production systems, new product applications, and/or future sulfur supply and demand.[5]

Conoco Inc. demonstrated that Claus sulfur recovery units can be economically expanded by 60% to 100% with the Claus oxygen-based process expansion technology. Two units at the company's Lake Charles, LA, refinery achieved an 85% increase in capacity by virtue of enriching the process air supply to 55% oxygen.[6]

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[1]Physical scientist, Division of Industrial Minerals.

[2]European Chemical News (London). V. 44, No. 1175, 1985, p. 30.

[3]The Oil and Gas Journal. V. 84, No. 5, 1986, p. 29.

[4]Work cited in footnote 2.

[5]The British Sulphur Corp. Ltd. of United Kingdom. Proceedings of Sulphur—85. An International Conference (London, England, Nov. 10-13, 1985). 297 pp.

[6]The Oil and Gas Journal. V. 83, No. 30, 1985, pp. 39-41.

# Talc and Pyrophyllite

## By Robert L. Virta[1]

Total domestic production of talc and pyrophyllite combined increased 13% from that of 1984, and sales of crude and processed ore increased slightly. Exports of talc decreased 7% in tonnage and 12% in value.

**Domestic Data Coverage.**—Domestic production and sales data for talc and pyrophyllite are developed by the Bureau of Mines from a voluntary survey of U.S. mines and mills. Of the 98 mines and mills to which a survey request was sent, 80 responded, representing 82% of the U.S. production data shown in table 1. Production for the nonrespondents was estimated using reported prior year production levels adjusted by trends in employment and other guidelines.

**Table 1.—Salient talc and pyrophyllite statistics**

(Thousand short tons and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Mine production, crude: | | | | | |
| Talc | 1,236 | 1,049 | 980 | [r]1,042 | 1,188 |
| Pyrophyllite | 107 | 87 | 87 | 85 | 81 |
| Total[1] | 1,343 | 1,135 | 1,066 | [r]1,127 | 1,269 |
| Value: | | | | | |
| Talc | $21,600 | $19,540 | $18,998 | [r]$21,755 | $27,768 |
| Pyrophyllite | 1,016 | 1,131 | 1,282 | 1,412 | 1,420 |
| Total | 22,616 | 20,671 | 20,280 | [r]23,167 | 29,188 |
| Sold by producers, crude and processed: | | | | | |
| Talc | 1,115 | 915 | 1,038 | [r]1,101 | 1,067 |
| Pyrophyllite | 106 | 110 | 125 | 97 | 139 |
| Total | 1,221 | 1,025 | 1,163 | [r]1,198 | 1,206 |
| Value: | | | | | |
| Talc | $95,354 | $82,104 | $104,739 | [r]$112,515 | $114,542 |
| Pyrophyllite | 3,454 | 3,557 | 4,057 | 3,578 | 5,101 |
| Total | 98,808 | 85,661 | 108,796 | [r]116,093 | 119,643 |
| Exports[2] (talc) | 311 | 232 | 218 | 256 | 237 |
| Value | $15,095 | $12,957 | $12,916 | $16,162 | $14,282 |
| Imports for consumption (talc) | [3]27 | [3]27 | 44 | 45 | 47 |
| Value | [3]$5,834 | [3]$6,264 | $7,691 | $9,156 | $9,532 |
| Apparent consumption[4] | 937 | 820 | 989 | 1,009 | 1,079 |
| World: Production | [r]8,012 | [r]7,777 | 7,795 | [p]8,351 | [e]8,305 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Data may not add to totals shown because of independent rounding.

[2] Excludes powders—talcum (in package), face, and compact.

[3] Does not include imported pyrophyllite.

[4] Production, plus imports, minus exports, plus adjustments in Government and industry stock changes.

**Legislation and Government Programs.**—On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. Although tier I and II stockpile requirements for talc and pyrophyllite have yet to be evaluated, the stockpile inventory was 1,081 short tons for block or lump talc and 1,089 tons for ground talc at yearend. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

The allowable depletion rates established under the Tax Reform Act of 1969 remained at 22% for domestic and 14% for foreign block steatite.

U.S. import duties on talc minerals from most favored nations were crude and unground, 0.02 cent per pound; ground, washed, powdered, and/or pulverized, 3.3% ad valorem; cut, sawed, or in blanks, crayons, cubes, disks, or other forms, free; and other not specifically provided for, 4.8% ad valorem.

## DOMESTIC PRODUCTION

**Talc.**—U.S. mine production of crude talc increased 14% in tonnage and 28% in value. Talc, including soapstone, was produced at 26 mines in 10 States. Eleven mines operated in California. Montana, New York, Texas, and Vermont accounted for 90% of domestic talc production. Montana led all States in the tonnage and value of talc produced.

The largest domestic producers of talc, listed alphabetically, are Cyprus Industrial Minerals Co. and Pfizer Inc., Minerals, Pigments & Metals Div., with mines in California and Montana; R. T. Vanderbilt Co. Inc. in New York; and Windsor Minerals Inc. in Vermont and California.

The Montana Talc Co., a joint venture between NICOR Mineral Ventures and Meridian Land and Minerals Co., began construction of a $12 million mine and mill operation near Ennis, MT.[2] The mine, in the Madison River Valley and adjacent to Cyprus Industrial Minerals' Yellowstone talc mine, had an identified reserve of 1 million tons. Production of 20,000 tons was planned for the first year of operation, gradually increasing to 100,000 tons.

Cyprus Industrial Minerals filed environmental impact statements with the State of Vermont for the construction of an underground talc mine and a processing plant near Chester. The operation would cost $10 to $20 million and employ 50 to 60 workers. The designed annual capacity of the plant would be 40,000 tons.

**Pyrophyllite.**—Pyrophyllite was mined by four companies operating seven mines in California and North Carolina. Total production decreased slightly from that of 1984.

Piedmont Minerals Co. Inc. increased the andalusite content of its refractory-grade products by adding a second heavy-media separation phase to the beneficiation process.[3] The andalusite content was increased from 40% to 50%, and the alumina content was increased from 29% to 35%. The addition of a flotation stage after the heavy-media separation in a pilot plant increased the andalusite content of the final product to 90%.

R. T. Vanderbilt announced plans to improve its beneficiation facilities at the Robbins and Glendon deposits in North Carolina. The particle size distribution of its products will be controlled more precisely, allowing the company to market more products. Coarse material from the process will be suitable for some ceramic applications and in textured paints. Fine material may be used as filler in plastics.

### Table 2.—Crude talc and pyrophyllite produced in the United States, by State

(Thousand short tons and thousand dollars)

| State | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity | Value | Quantity | Value |
| California | 74 | 1,642 | 100 | 2,493 |
| Georgia (talc) | 15 | 104 | 16 | 111 |
| North Carolina | 87 | 1,587 | 85 | 1,604 |
| Texas (talc) | [r]240 | [r]4,125 | 261 | 5,245 |
| Other[1] (talc) | 711 | [r]15,709 | 807 | 19,735 |
| Total | [r]1,127 | [r]23,167 | 1,269 | 29,188 |

[r] Revised.

[1] Includes Arkansas, Montana, New York, Oregon, Vermont, and Virginia.

## CONSUMPTION AND USES

Apparent domestic consumption of crude and processed talc and pyrophyllite increased 7%. Sales of talc and pyrophyllite increased slightly in tonnage and value.

End-use distribution of ground talc was ceramics, 32%; paint, 16%; paper, 14%; roofing, 11%; plastics, 8%; cosmetics, 5%; rubber, 3%; and insecticides, 1%.

The largest portion, 58%, of domestically produced ground pyrophyllite was used in ceramics; 16% was used in refractories, and 10% in insecticides.

The paint industry is gradually shifting from solvent-based paints to alternative paint formulas because of production costs and environmental and safety problems.[4] Water-based paints are used more extensively, but high-solid paints and powder coatings are promising alternatives to solvent-based paints. All three of these alternatives use extenders to reduce the cost of paint production and to modify the characteristics of the paint. These extenders are selected by chemical composition, refractive index, particle size, particle shape, and particle size distribution. Calcium carbonate, kaolin, and talc are the major extenders used in the United States. Pyrophyllite is a minor extender used only in textured paints.

Approximately 200,000 tons of talc was used by the U.S. paint industry in 1985. Talc is useful as an extender in high-solid paints because it is hydrophobic and disperses well in oleoresinous media, it reduces the amount of solvent required, and it has flatting and antisettling properties. For water-based paints, it is necessary to treat the talc with a deflocculant. Although most talc used is platy, fibrous talc is valuable as an extender because of the high oil absorption properties, good rheological characteristics, and good antisettling properties.

**Table 3.—End uses for ground talc and pyrophyllite**

(Thousand short tons)

| Use | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Talc | Pyrophyllite | Total | Talc | Pyrophyllite | Total |
| Ceramics | 358 | [r]85 | [r]448 | 296 | 72 | 368 |
| Cosmetics[1] | 44 | -- | 44 | 46 | 3 | 49 |
| Insecticides | 8 | 14 | 22 | 7 | 12 | 19 |
| Paint | 189 | 1 | 190 | 144 | 2 | 146 |
| Paper | 100 | -- | 100 | 125 | -- | 125 |
| Plastics | 67 | 1 | 68 | 70 | 1 | 71 |
| Refractories | 4 | 21 | 25 | 5 | 20 | 25 |
| Roofing | 86 | 6 | 92 | 100 | 2 | 102 |
| Rubber | 29 | -- | 29 | 27 | -- | 27 |
| Other[2] | 85 | 11 | 96 | 101 | 12 | 113 |
| Total | 970 | [r]139 | [r]1,109 | 921 | 124 | 1,045 |

[r] Revised.

[1] Incomplete data. Some cosmetic talc known to be included with "Other."

[2] Includes art sculpture, asphalt filler and coatings, crayons, floor tile, foundry facings, rice polishing, stucco, and uses not specified.

## PRICES

Talc prices varied depending on quality and on degree and method of processing.

Prices, quoted by the Engineering and Mining Journal, December 1985, per short ton of domestic ground talc, in carload lots, f.o.b. mine or mill, including containers follow:

| | |
|---|---|
| New Jersey: | |
| Mineral pulp, bags extra | $18.50-$20.50 |
| Vermont: | |
| 98% through 325 mesh, bulk | 70.00 |
| 99.99% through 325 mesh, bags: | |
| Dry processed | 147.00 |
| Water beneficiated | 213.00-228.00 |
| New York: | |
| 96% through 200 mesh | 62.00- 75.00 |
| 98% to 99.25% through 325 mesh | 85.00-100.00 |
| 100% through 325 mesh, fluid-energy ground | 165.00 |
| California: | |
| Standard | 130.00 |
| Fractionated | 37.00- 71.00 |
| Micronized | 150.00-220.00 |
| Cosmetic steatite | 44.00- 65.00 |
| Georgia: | |
| 98% through 200 mesh | 50.00 |
| 99% through 325 mesh | 60.00 |
| 100% through 325 mesh, fluid-energy ground | 100.00 |

Approximate equivalents, in dollars per short ton, of price ranges quoted in Industrial Minerals (London), December 1985, for talc, c.i.f. main European ports, follow:

| | |
|---|---|
| Australian, cosmetic (ex store) | $182-$196 |
| Norwegian: | |
| Ground (ex store) | 126- 140 |
| Micronized (ex store) | 154- 224 |
| French, fine-ground | 126- 238 |
| Italian, cosmetic-grade | 231 |
| Chinese, normal (ex store): | |
| UK 200 mesh | 186 |
| UK 325 mesh | 196 |
| New York, paint, minimum 20-ton lot | 245 |

## FOREIGN TRADE

**Exports.**—Talc exports decreased 7%, while their value decreased 12%. Prices ranged from $27 to $440 per ton, averaging $60 per ton.

Mexico was the major importer of U.S. talc, accounting for 46% of the tonnage shipped, followed by Canada, 34%; Japan, 8%; and Belgium-Luxembourg, 3%. Canada led in value of imports with 34% of the total, followed by Mexico with 31%. Fifty-five countries imported U.S. talc.

**Imports.**—U.S. imports for consumption of talc increased 5%. Imports from Canada increased 20%. Canada was the leading source of imported talc with 63%, followed by Italy with 12% and France with 11%. Canada, Italy, and China accounted for 71% of the value of all imported talc.

### Table 4.—U.S. exports of talc[1]

(Thousand short tons and thousand dollars)

| Year | Belgium-Luxembourg | | Canada[2] | | Japan | | Mexico | | Other[3] | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| 1981 | 17 | 1,364 | 79 | 4,632 | 9 | 500 | 164 | 4,256 | 42 | 4,343 | 311 | 15,095 |
| 1982 | 18 | 1,263 | 63 | 4,208 | 9 | 439 | 102 | 3,083 | 40 | 3,964 | 232 | 12,957 |
| 1983 | 1 | 55 | 74 | 4,629 | 16 | 1,077 | 86 | 2,805 | 41 | 4,350 | 218 | 12,916 |
| 1984 | 11 | 722 | 76 | 5,265 | 22 | 1,518 | 107 | 3,696 | 40 | 4,961 | 256 | 16,162 |
| 1985 | 6 | 373 | 81 | 4,864 | 18 | 1,422 | 108 | 4,492 | 24 | 3,131 | 237 | 14,282 |

[1] Excludes powders—talcum (in package), face, and compact.

[2] Probably includes shipments in transit through Canadian ports.

[3] Includes 51 countries.

**Table 5.—U.S. imports for consumption of talc, by country**

| Country | Crude and unground | | Ground, washed, powdered, or pulverized | | Cut and sawed | | Talc, n.s.p.f. | Total unmanufactured | |
|---|---|---|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| 1983 | 20,922 | 2,271 | 21,701 | 3,615 | 1,371 | 853 | 952 | 43,994 | 7,691 |
| 1984: | | | | | | | | | |
| Brazil | -- | -- | 116 | 23 | 1,215 | 482 | 7 | 1,331 | 512 |
| Canada | 24 | 1 | 24,586 | 3,911 | 205 | 208 | 23 | 24,815 | 4,148 |
| China | -- | -- | -- | -- | 179 | 169 | 355 | 179 | 524 |
| India | -- | -- | NA | 93 | 13 | 36 | 417 | 13 | 546 |
| Italy | 9,315 | 1,706 | 137 | 48 | -- | -- | -- | 9,452 | 1,754 |
| Korea, Republic of | -- | -- | 2,434 | 798 | 104 | 50 | -- | 2,538 | 848 |
| Other[1] | 5,529 | 333 | 705 | 253 | 91 | 85 | 158 | 6,325 | 829 |
| Total | 14,868 | 2,040 | 27,978 | 5,126 | 1,807 | 1,030 | 960 | 44,653 | 9,156 |
| 1985: | | | | | | | | | |
| Brazil | -- | -- | 143 | 23 | 1,220 | 464 | 16 | 1,363 | 503 |
| Canada | 10 | 2 | 29,524 | 4,111 | 131 | 180 | 29 | 29,665 | 4,322 |
| China | -- | -- | -- | -- | 1,013 | 889 | 271 | 1,013 | 1,160 |
| France | 4,217 | 240 | 838 | 130 | -- | -- | -- | 5,055 | 370 |
| Italy | 5,511 | 1,025 | 84 | 21 | 155 | 251 | -- | 5,750 | 1,297 |
| Korea, Republic of | 437 | 44 | 1,672 | 344 | 92 | 54 | -- | 2,201 | 442 |
| Other[2] | 597 | 39 | 973 | 511 | 278 | 259 | 629 | 1,848 | 1,438 |
| Total | 10,772 | 1,350 | 33,234 | 5,140 | 2,889 | 2,097 | 945 | 46,895 | 9,532 |

NA Not available.
[1] Includes 23 countries.
[2] Includes 15 countries.

Source: Bureau of the Census.

## WORLD REVIEW

The United States remained the world's largest talc producer, and Japan remained the largest pyrophyllite producer. The United States, Japan, and China accounted for 48% of the world's talc and pyrophyllite production.

**Australia.**—Westside Mines Pty. Ltd., which supplied almost 50% of the talc used by the United Kingdom's cosmetic manufacturers, closed its Mount Seabrook talc mine because legal ownership of the mine was being contested.[5]

Thames Mining NL, part of Keywest Investments Group, began exploration of the Livingston talc deposit, 4 miles from the Mount Seabrook deposit.[6] The talc deposit occurs in a deformed quartz-muscovite schist and was believed to be geologically related to the Mount Seabrook deposit. Preliminary drilling indicated substantial reserves of talc.

**Brazil.**—Mineração Matheus Leme Ltda. began operating its Minas Gerais pyrophyllite processing facility in June.[7] The rated capacity of the plant was 50,000 tons per year of pyrophyllite for use in the paint and rubber industries.

**Canada.**—Steetley Talc Ltd. began a $3 million expansion at the Timmins plant in Ontario to increase the capacity to 60,000 tons per year and increase the number of talc grades produced.[8] The expansion was phase 2 of a three-phase program to increase production capacity to 120,000 tons per year. The improvements included refurbishing the ball mill, classifiers, drum filters, magnetic separators, and thickeners, and installing a micronizing plant, a Raymond mill, and concentrators.

Talcs de Luzenac S.A., a major French talc producer, acquired a 50% share of Broughton Soapstone and Quarry Co. Ltd. (BSQ).[9] BSQ produced and marketed talc from deposits in the Thetford region of Quebec for roofing materials, the rubber industry, and other construction applications. The company planned a $700,000 expansion to double plant capacity to 50,000 tons per year. High-grade products for the plastics and paper industry will be produced through selective mining.

**France.**—Talcs de Luzenac, the largest talc-producing group worldwide, increased sales of talc to the British cosmetic industry to approximately 3,500 tons.[10] The increase in sales from France was partly attributed to the closing of Westside Mines' Mount Seabrook Mine, which had supplied almost 50% of the talc for the British cosmetic industry. The company also installed a laser selection process in its plant in the Ariège Pyrenees to supplement hand cobbing.

**United Kingdom.**—The cosmetic industry consumed approximately 15,000 tons of talc valued at $45 million after sterilization.[11] Talc was selected according to its end use. Properties such as macroscopic and microscopic appearance, chemistry, color, density, odor, and texture were important in this selection. For example, particle size and shape influenced the bulk handling properties of the talc and its softness and absorbency. Chemistry affected the color and the stability of tints and perfumes. Mineral impurities affected abrasiveness and color stability. The properties of talc were frequently enhanced by adding other minerals or chemicals.

Additives such as calcium carbonate, kaolin, metallic stearates, and starch were used to improve absorbency, adhesion, color, density, and bulk powder characteristics.

The comestic manufacturers changed talc suppliers following the shutdown of Westside Mines in May. Westside Mines supplied 45% to 55% of the cosmetic talc to the British cosmetic industry. Belgium, Italy, and Spain were other major suppliers of talc.

### Table 6.—Talc and pyrophyllite: World production, by country[1]

(Short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina (talc, steatite, pyrophyllite) | 39,925 | 31,849 | 32,729 | 30,629 | 29,000 |
| Australia | 91,476 | 168,424 | 204,964 | [r] [e]276,000 | 276,000 |
| Austria (unground talc) | 128,336 | 129,072 | 134,623 | 147,722 | 143,000 |
| Brazil (talc and pyrophyllite)[3] | 555,184 | 446,731 | 437,025 | 455,637 | 468,500 |
| Burma | 141 | 141 | 141 | 141 | 145 |
| Canada (shipments) | [r]91,178 | 79,567 | 106,924 | 138,891 | 143,000 |
| Chile | 733 | 312 | 702 | 465 | 440 |
| China[e] | 990,000 | 1,050,000 | 1,050,000 | 1,050,000 | 1,100,000 |
| Colombia | 6,669 | 6,878 | 7,318 | 7,479 | 7,400 |
| Egypt | 6,309 | 9,139 | 4,981 | 13,463 | 13,000 |
| Finland | 339,418 | 358,251 | 351,009 | 360,976 | 364,000 |
| France (ground talc) | 340,911 | 304,723 | 315,812 | 322,315 | 331,000 |
| Germany, Federal Republic of (marketable) | 17,021 | 16,789 | 15,773 | [e]15,000 | 15,000 |
| Greece (steatite) | 2,788 | 2,973 | 2,388 | [r] [e]2,400 | 2,400 |
| Hungary[e] | 19,300 | 18,700 | 18,700 | 19,300 | 18,700 |
| India (pyrophyllite and steatite) | 405,175 | 379,129 | 389,162 | 460,473 | 441,000 |
| Italy (talc and steatite) | 180,106 | 180,746 | 175,239 | 157,329 | [4]142,875 |
| Japan[5] | 1,703,125 | 1,644,982 | 1,615,791 | 1,652,303 | [4]1,580,978 |
| Korea, North[e] | 185,000 | 185,000 | 185,000 | 185,000 | 185,000 |
| Korea, Republic of (talc and pyrophyllite) | 622,383 | 651,594 | 696,810 | 935,475 | 772,000 |
| Mexico | [r]15,138 | 13,525 | 12,161 | 9,811 | 10,000 |
| Nepal[6] | 78 | 3,310 | 16,825 | 8,372 | 11,000 |
| Norway[e] | [4]93,981 | [r]110,000 | [r]110,000 | [r]110,000 | 110,000 |
| Pakistan (pyrophyllite) | [r]27,482 | [r]22,669 | 17,588 | 17,161 | 20,800 |
| Paraguay | 165 | 165 | 132 | 165 | 140 |
| Peru (talc and pyrophyllite)[e] | 10,000 | 9,500 | 9,500 | 9,000 | 9,000 |
| Philippines | 492 | 1,111 | 968 | 442 | 1,100 |
| Portugal | 7,014 | 5,445 | 6,018 | 6,838 | 6,900 |
| Romania[e] | 66,000 | 66,000 | 66,000 | 72,000 | 72,000 |
| South Africa, Republic of[7] | 16,674 | 15,226 | 12,337 | 15,886 | [4]15,925 |
| Spain (steatite) | 76,134 | 69,099 | 76,574 | 79,628 | 80,500 |
| Sweden | 17,175 | 19,569 | 23,210 | 22,046 | 22,000 |
| Taiwan | 27,309 | 33,798 | 29,821 | 20,591 | 20,000 |
| Thailand (talc and pyrophyllite) | 13,266 | 24,249 | 22,209 | 31,393 | 32,000 |
| U.S.S.R.[e] | 550,000 | 560,000 | 560,000 | 570,000 | 570,000 |
| United Kingdom[e] | 19,800 | 21,000 | 17,600 | 17,600 | 19,800 |
| United States (talc and pyrophyllite) | 1,342,916 | 1,135,415 | 1,066,400 | 1,127,421 | [4]1,268,750 |
| Uruguay | [e]1,900 | 1,262 | 755 | [e]1,300 | 1,100 |
| Zambia | 1,015 | 299 | 1,447 | 405 | 440 |
| Zimbabwe | 425 | 298 | 607 | 314 | 330 |
| Total | [r]8,012,142 | [r]7,776,940 | 7,795,243 | 8,351,371 | 8,305,223 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Table includes data available through May 27, 1986.

[2] In addition to the countries listed, Czechoslovakia produces talc, but available information is inadequate to make reliable estimates of output levels.

[3] Total of beneficiated and salable direct-shipping production of talc and pyrophyllite.

[4] Reported figure.

[5] Includes talc, pyrophyllite, and pyrophyllite clay.

[6] Data based on Nepalese fiscal year beginning mid-July of year stated.

[7] Includes talc and wonderstone.

## TECHNOLOGY

The cost of plastics is reduced by adding talc as a filler.[12] Talc is one of the few minerals used by the plastics industry as a reinforcing filler. The platy nature of the talc provides a rigidity to the composite. Plastics with talc fillers exhibit a higher stiffness and creep resistance at ambient and elevated temperatures compared to plastics with particulate fillers such as calcium carbonate. For example, a polypropylene containing 40% loading of talc filler has a stiffness 3 times that of polypropylene with no filler and 1.5 times that of polypropylene containing a 40% loading of calcium carbonate filler. Talc has additional advantages over other mineral fillers because it is soft, requires less energy to mine, and was less abrasive in processing.

A major problem encountered when using high loadings of fillers is a reduction of impact strength. This is minimized for talc fillers by selecting the proper particle size distribution, treating the surface of the talc particles, and selecting the proper resin formulations. In 1985, the use of surface treatment increased approximately 15%.[13] Particle surfaces were chemically altered using silanes, stearates, and organometallics to improve the bond between the filler and the resins. For siliceous fillers, such as talc, silanes offered an advantage over stearates and organometallics by containing an organic to react with the resin and an inorganic to react with the siliceous filler.

A mineralogical study of a fibrous talc sample from New York examined the phase relationships between the fibrous talc and amphiboles in the sample.[14] Two amphibole phases were present. Nonasbestiform tremolite occurred as a separate phase. Fibrous anthophyllite was intimately intermixed with the fibrous talc within single grains. The intermixing of the anthophyllite and talc within single grains was significant with regard to a provisional transmission electron microscopy (TEM) technique for identifying amphibole asbestos in talc. The provisional technique did not positively identify the anthophyllite because of the crystallographic relationship between the talc and anthophyllite. A more extensive TEM technique employing electron diffraction and energy-dispersive X-ray analysis was recommended.

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[1] Physical scientist, Division of Industrial Minerals.

[2] Rocky Mountain Paydirt. Feb. 1986.

[3] Dickson, T. North American Pyrophyllite-Ceramics Leading the Way. Ind. Miner. (London), No. 218, Nov. 1985, p. 57.

[4] Toon, S. Minerals for Paint. Ind. Miner. (London), No. 219, Dec. 1985, pp. 49-75.

[5] Industrial Minerals (London). Comment. No. 215, Aug. 1985, p. 7.

[6] ———. World of Minerals. No. 218, Nov. 1985, p. 9.

[7] ———. World of Minerals. No. 215, Aug. 1985, p. 9.

[8] Page 10 of work cited in footnote 7.

[9] Industrial Minerals (London). World of Minerals. No. 209, Feb. 1985, p. 9.

[10] ———. Fillers and Extenders. No. 218, Nov. 1985, p. 89.

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[13] Harben, P. Fine Particles and Fillers, A Conference Report. Ind. Miner. (London), No. 222, Mar. 1986, pp. 153-157.

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# Thorium

## By James B. Hedrick[1]

Domestic mine production of monazite, the principal source of thorium, increased in 1985 for the fifth successive year; however, output was exported. Thorium products used domestically were derived from imported materials, existing company stocks, and thorium nitrate released from the National Defense Stockpile (NDS). W. R. Grace & Co.'s Davison Chemical Div. and Rhône-Poulenc Inc., a subsidiary of Rhône-Poulenc S.A. of France, were the principal processors of thorium-containing ores in the United States. Magnesium Elektron Inc. was the principal domestic supplier of thorium alloys from its facilities in the United Kingdom.

Major nonenergy end uses were in aerospace alloys, mantles for incandescent lanterns, welding electrodes, and refractory applications. The only energy use of thorium in the United States was in the high-temperature gas-cooled nuclear reactor at Fort St. Vrain, CO.

**Domestic Data Coverage.**—Domestic mine production data for thorium-bearing monazite are developed by the Bureau of Mines from a voluntary survey of U.S. operations, the "Rare Earths and Thorium" survey. The one mine to which a survey form was sent responded, representing 100% of total production. Mine production data for thorium contained in monazite are withheld to avoid disclosing company proprietary data.

**Table 1.—Salient U.S. thorium statistics**

(Metric tons of $ThO_2$, unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Exports: Ores and metals | 6 | 4 | 4 | 11 | 32 |
| Imports: Compounds, gas mantles, metals | 33 | 23 | 46 | 45 | 69 |
| Shipments from Government stockpile excesses | 3 | -- | -- | -- | 2 |
| Apparent consumption, nonenergy applications[e] [1] | 30 | 19 | 42 | 34 | 39 |
| Prices, yearend, dollars per kilogram, $ThO_2$:[2] | | | | | |
| Nitrate, mantle-grade | $9.50 | $10.60 | $10.60 | $10.10 | $10.10 |
| Oxide, 99% grade | $21.20 | $24.50 | $31.00 | [r]$35.85 | $35.85 |

[e] Estimated. [r] Revised.

[1] All domestically consumed thorium was derived from imported metals, alloys, and compounds; monazite containing 350 to 550 tons of thorium oxide has been imported annually but has not been used to produce thorium products until 1985.

[2] Rhône-Poulenc Inc.

**Legislation and Government Programs.**—Sales of materials held in the NDS, including thorium nitrate, were suspended in September because the $250 million limit imposed on the General Services Administration's (GSA) transaction fund was reached. Exceptions to the transaction fund limit include authority to sell materials held by GSA in non-NDS stockpiles and to trade NDS materials declared as excess in exchange for upgrading of materials specified under the Presidential Ferroalloy Program. Thorium nitrate from the NDS that had previously been declared as excess to goal was sold in 1985 as authorized by the Department of Defense Authorization Act, 1985 (Public Law 98-525), effective September 30, 1984. A total of 4,536 kilograms (10,000 pounds) of the 22,680 kilograms (50,000 pounds) of thorium nitrate authorized for disposal under this law was sold before the transaction fund limit was reached.

**Environmental Impact.**—Radioactivity levels at the Bureau of Mines Albany Research Center were reportedly above the Federal limits owing to thorium, radium, and uranium contamination in the soil and the Center's research laboratories. The contamination was discoverod in 1983 by officials of the Oregon State Department of Environmental Quality and confirmed by subsequent studies made by Bechtel National Inc., under contract to the Government. The contamination was the result of byproduct waste generated from research conducted during the 1940's related to processing various thorium-bearing ores, metals, and alloys, for the Atomic Energy Commission.[2] Cleanup of the contamination was expected to be completed by fiscal 1988.

Teledyne Wah Chang Albany (TWC) continued to experience problems resulting from environmental concerns over the storage of slightly radioactive process sludge containing thorium, uranium, and radium derived from naturally occurring minerals at its Albany, OR, facilities. TWC reportedly applied for a license to allow it to retain the sludge at its plantsite and strengthen and cover the disposal pond.[3] Removal of the sludge to an out-of-State disposal site would reportedly cost the company an estimated $100 million, according to company sources.

## DOMESTIC PRODUCTION

Associated Minerals Ltd. Inc., a subsidiary of the Australian-owned firm Associated Minerals Consolidated Ltd. (AMC), a wholly owned subsidiary of Renison Goldfields Consolidated Ltd. (RGC) of Australia, was the only commercial minerals sands operation in the United States to produce monazite in 1985. Monazite was produced as a byproduct of minerals sands mined for titanium and zirconium minerals at Green Cove Springs, FL. Associated Minerals was engaged in domestic exploration for additional minerals sands to increase its reserves in the United States.

Table 2.—U.S. companies with thorium processing and fabricating capacity

| Company | Plant location | Operations and products |
|---|---|---|
| Atomergic Chemetals Corp | Plainview, NY | Produces oxide, fluoride, metal. |
| Bettis Atomic Power Laboratory | West Mifflin, PA | Nuclear fuels; Government research and development. |
| Cerac Inc | Milwaukee, WI | Produces ceramics. |
| Ceradyne Inc | Santa Ana, CA | Produces advanced technical ceramics. |
| Chicago Magnesium Castings Co | Blue Island, IL | Magnesium-thorium alloys. |
| Coleman Co. Inc | Wichita, KS | Produces thoriated mantles. |
| Consolidated Aluminum Corp | Madison, IL | Magnesium-thorium alloys. |
| Controlled Castings Corp | Plainview, NY | Do. |
| GA Technologies Inc | San Diego, CA | Nuclear fuels. |
| W. R. Grace & Co., Davison Chemical Div | Chattanooga, TN | Produces thorium-containing residues from monazite. |
| GTE Sylvania | Towanda, PA | Produces thoriated welding rods. |
| Hitchcock Industries Inc | South Bloomington, MN | Magnesium-thorium alloys. |
| NLO Inc.[1] | Cincinnati, OH | Produces compounds and metals; manages DOE thorium stocks. |
| North American Phillips Lighting Corp | Bloomfield, NJ | Produces thorium-containing lighting and metallic thorium. |
| Phillips Elmet | Lewiston, ME | Produces thoriated welding rods. |
| Rhône-Poulenc Inc | Freeport, TX | Produces thorium nitrate from an intermediate compound of monazite. |

See footnote at end of table.

**Table 2.—U.S. companies with thorium processing and fabricating capacity —Continued**

| Company | Plant location | Operations and products |
|---|---|---|
| Teledyne Cast Products | Pomona, CA | Magnesium-thorium alloys. |
| Teledyne Wah Chang | Huntsville, AL | Produces thoriated welding rods. |
| Union Carbide Corp., Nuclear Div | Oak Ridge, TN | Nuclear fuels; test quantities. |
| Wellman Dynamics Corp | Creston, IA | Magnesium-thorium alloys. |

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[1] Manager of U.S. Department of Energy stocks; will become Westinghouse Materials Co. of Ohio, effective Jan. 1, 1986.

## CONSUMPTION AND USES

Domestic thorium processors reported consumption of an estimated 74 metric tons of thorium oxide equivalent in 1985, an increase of 23 tons above the 1984 level. Nonenergy uses accounted for about 69 tons of the total, and energy uses accounted for the remainder. The approximate distribution of nonenergy thorium consumption by end use, based on information supplied by producers, primary processors, and several consumers, was as follows: refractory applications, 75%; aerospace alloys, 11%; lamp mantles, 8%; welding electrodes, 2%; and other applications, including ceramics and lighting, 4%.

Nearly all of the thorium used in metallurgical applications was alloyed with magnesium. Magnesium-thorium alloys used by the aerospace industry are lightweight and possess high strength and excellent creep resistance at elevated temperatures, properties that are useful in aircraft applications. Small quantities of thorium oxide (thoria) were used in dispersion-hardened alloys for high-strength, high-temperature applications.

Thorium oxide has the highest melting point of all the oxides at 3,300° C, a property that contributed to its use in several refractory applications, including high-strength, high-temperature ceramics; investment molds; crucibles; and research on heat-dissipative core-retention beds for nuclear reactors.

Thorium nitrate was used in the manufacture of mantles for incandescent "camping" lanterns and for oil lamps. Thorium nitrate was also used to produce thoriated tungsten welding electrodes. Thoriated tungsten electrodes were used to join stainless steels, nickel alloys, and other alloys that usually require controlled weld performance.

Thorium was used in electron tubes, in bulbs to light airport runways, in special high-refractivity glass, in radiation detectors, in computer memory components, in catalysts, in photoconductive films, in target materials for X-ray tubes, and in fuel cell elements.

In energy applications, thorium was used as a nuclear fuel in the thorium-232/uranium-233 fuel cycle in one domestic commercial reactor.

## STOCKS

Government stocks of thorium nitrate in the NDS were 3,230,400 kilograms (1,544,845 kilograms of equivalent thorium oxide) on December 31, 1985. The NDS goal at yearend was 272,155 kilograms of thorium nitrate (130,153 kilograms of equivalent thorium oxide); remaining stocks have been declared excess to goal. However, the Department of Defense Authorization Act, 1985, authorized for disposal only 22,860 kilograms (50,000 pounds) of the thorium nitrate stocks held in the stockpile. Of this amount, 18,144 kilograms (40,000 pounds) of thorium nitrate remains authorized for disposal, but sales of the material were suspended in September 1985 as a result of a ceiling limit of $250 million placed on receipts in the stockpile transaction fund.

The U.S. Department of Energy's inventory at yearend contained 1,242,868 kilograms of thorium oxide equivalent contained in ore, metal, and various compounds.

## PRICES

The average declared value of imported monazite decreased during 1985 to $349 per ton, down $40 from the 1984 value. The price range of Australian monazite, minimum 55% rare-earth oxide including thoria (f.o.b.-f.i.d.[4]), as quoted in Australian dollars (A$) in Metal Bulletin (London), increased sharply from A$410-A$440 per ton at yearend 1984 to A$850-A$900 per ton by yearend 1985. Changes in the foreign exchange rate in 1985, resulting from the continued economic strength of the U.S. dollar against foreign currencies, caused the corresponding U.S. price to rise less sharply from the range of $340-$365 in 1984[5] to $580-$614 in 1985.[5]

The yearend price for monazite, based on a thorium oxide content of 7%, was approximately $8.29 to $8.78 per kilogram of thorium oxide contained.

Rhône-Poulenc Inc. quoted prices for thorium oxide, per kilogram, net 30 days, f.o.b. Freeport, TX, or duty paid at point of entry, effective January 1, 1985, were 99% purity—$37.65 and 99.99% purity—$57.75. Thorium nitrate at 99.5% purity (mantle grade) was quoted at $10.10 per kilogram of thorium oxide equivalent at yearend.

Thorium alloy prices quoted from Magnesium Elektron, Flemington, NJ, were $30.11 per pound for thorium hardener alloy and $4.58 per pound for HZ-type alloy ingot.

## FOREIGN TRADE

For the sixth consecutive year, France was the destination of all of the domestic exports of thorium ore, including monazite. Australia has been the principal domestic source of thorium-bearing monazite since 1977. Until 1985, monazite was imported solely for its rare-earth content, and no thorium products had been produced from it. Thorium products processed and manufactured domestically in 1985 were derived mainly from imported materials, primarily thorium compounds and rare-earth concentrates from France and magnesium-thorium alloys from the United Kingdom.

### Table 3.—U.S. foreign trade in thorium and thorium-bearing materials

(Quantity in kilograms unless otherwise specified)

| | 1983 | | 1984 | | 1985 | | Principal destinations and sources, 1985 |
|---|---|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Quantity | Value | |
| **EXPORTS** | | | | | | | |
| Thorium ore, monazite | 57,139 | $51,678 | 229,983 | $157,608 | 743,103 | $415,024 | All to France. |
| Metals[1] | 937 | 48,882 | 890 | 46,905 | 1,440 | 182,373 | United Kingdom 615; France 589; Netherlands 134; other 102. |
| **IMPORTS** | | | | | | | |
| Ore and concentrate: | | | | | | | |
| Thorium ore, monazite — metric tons | 4,028 | 1,517,299 | 5,661 | 2,202,377 | 5,694 | 1,984,486 | All from Australia. |
| $ThO_2$ content | 284,980 | XX | 395,760 | XX | 398,580 | XX | |
| Compounds: | | | | | | | |
| Nitrate | 17,438 | 191,871 | 17,957 | 220,360 | 16,848 | 210,910 | France 13,699; Canada 3,149. |
| Oxide | 35,844 | 825,393 | 35,026 | 299,994 | 50,777 | 841,331 | France 47,350; Netherlands 3,427. |
| Oxide equivalent, in gas mantles[e 2] | 1,193 | 505,589 | 1,169 | 426,230 | 1,877 | 449,112 | Malta 1,417; India 122; Hong Kong 107; Federal Republic of Germany 68; Canada 53; Brazil 51; Italy 38; China 22. |
| Other | 428 | 100,793 | 588 | 195,111 | 499 | 171,463 | United Kingdom 494; Switzerland 5. |
| Metals and alloys | 30,016 | NA | 79,990 | NA | 8,306 | NA | All from United Kingdom. |
| Unwrought, waste, and scrap | -- | -- | -- | -- | 680 | 18,334 | All from Canada. |

[e] Estimated. NA Not available. XX Not applicable.

[1] Unwrought, wrought, waste, and scrap.

[2] Based on the manufacture of 2,205 gas mantles per kilogram of thorium oxide.

Sources: Bureau of the Census and a producer.

## WORLD REVIEW

**Australia.**—RGC announced its bid to takeover control of Allied Eneabba Ltd. Several offers by RGC to gain control of Allied through stock purchases had occurred by yearend. The final takeover offer was to close on January 23, 1986, at which time RGC was expected to have acquired a controlling interest. The corporate takeover, if successful, would make RGC the world's principal minerals sands producer and the world's largest producer of thorium-containing monazite.[7]

Allied, in a joint venture with Asahi Chemical Industry Co. Ltd., was studying the feasibility of building a rare-earth and thorium separation plant at Geraldton, Western Australia, to process monazite. Monazite concentrates produced to date have been exported for further processing and separation, with Australian companies reportedly foregoing the added revenues to be gained through secondary refining.[8] RGC's takeover bid was not expected to affect the proposed Allied-Asahi separation plant venture.

Consolidated Rutile Ltd. (CRL) reportedly began minerals sands production at the Gordon Lease property on the southern end of North Stradbroke Island, Queensland. The property was acquired by CRL from AMC, a wholly owned subsidiary of RGC, in the first quarter of 1985. CRL also completed an agreement with AMC for the acquisition of all of AMC's holdings on the island.[9]

A new company, $TiO_2$ Corp. NL, owned by Griffiths Bros. Ltd. (80%) and Spunthill Pty. Ltd. (20%), announced plans to mine minerals sands deposits at Jurien Bay and Cooljarloo in Western Australia. These deposits were previously worked by Western Mining Corp. in the mid-1970's. Cooljarloo's reserves were given as 16 million tons proven and 42 million tons probable ore grading 3% to 5% heavy minerals including monazite. The Cooljarloo deposit's monazite content averages about 0.2% of the heavy mineral suite. Reserves at Jurien Bay were listed at 25 million tons proven and 1 million tons probable ore grading 6% to 7% heavy minerals including monazite at 0.7% (12,700 tons of thorium oxide equivalent).[10] Production from Cooljarloo was planned for 1988.

Monazite production capacities for Cooljarloo and Jurien Bay were estimated at 400 tons (28 tons of thorium oxide equivalent) and 1,200 tons (84 tons of thorium oxide equivalent) per year, respectively.[11]

A joint venture by Strategic Minerals Corp. (SMC) and Rutile & Zircon Mines (Newcastle) Ltd. (RZM) was formed to explore and develop SMC's heavy minerals sands deposits at Byfield, Queensland. Reportedly, RZM can earn an 80% equity in the project by either the expenditure of $2.05 million or by completing a final feasibility study leading to a decision to mine.[12]

**Bangladesh.**—Reportedly, Bangladesh will spend $7 million on a 5-year plan to extract heavy minerals, including thorium-containing monazite from the Cox's Bazaar coastal area. The beach sands, 100 kilometers southeast of Chittagong, along the coast and on nearby islands, contain resources estimated at 5 million tons of heavy minerals.[13]

**Brazil.**—Minerals sands production began at Cumuruxatiba in Bahia State. Monazite along with ilmenite, rutile, and zircon were recovered at the mine. Concentrates produced at Cumuruxatiba were shipped to the São Paulo processing plant, operated by the state-controlled Nuclebras de Monazita e Associados Ltda., where thorium and rare-earth compounds were produced.[14]

Production of crude monazite ore in 1984 was 530 tons from the State of Espírito Santo, a decrease from the 915 tons produced in 1983, and 3,635 tons from the State of Rio de Janeiro, a decrease from the 1983 production level of 5,015 tons.

According to Anuário Mineral Brasileiro 1985, measured reserves of monazite were 13,705 tons for 1984. Estimated thorium oxide equivalent content based on these reserves was 890 tons. Monazite reserves were in the States of Espírito Santo, Paraná, and Rio de Janeiro.[15]

**France.**—Rhône-Poulenc S.A. announced it would invest 26.7 million in its two rare earth-thorium plants at La Rochelle, France, and Freeport, TX, in the United States. The additional funding would reportedly be used to increase the existing separation and production capacities.[16] Emphasis on increased separation of neodymium oxide and dysprosium oxide for use in high-strength permanent magnets was reportedly the principal reason for the investment.

**Germany, Federal Republic of.**—Further studies of heavy minerals sands deposits at Cuxhaven, discovered during a drilling program in 1973-76, were concluded in 1985 by the Federal Ministry for Research & Technology. Reserves were estimated at 10 million tons of heavy minerals sands including ilmenite, rutile, zircon, and possibly monazite. The fossilized beach sands deposits are reportedly similar to those on the east coast of Australia and were deposited during the late Tertiary era. Additional reserves are thought to occur in the area, and further exploration was scheduled.[17]

**India.**—Indian Rare Earths Ltd.'s dredge and wet concentrator plant began operation at the Orissa Sands Complex in Orissa. The dry mill was also commissioned and trial runs were being conducted.[18] Production of limited amounts of monazite concentrates associated with an initial production of 30,000 tons of ilmenite was reported.

**Zaire.**—Several tin and gold deposits in the Kivu region also contain monazite. Reserves of monazite in the Obaye mining sector, under the jurisdiction of the Zairian mining company Société Minière et Industrielle de Kivu, occur in two separate deposits. The Kabengelwa deposit contains 1,100 tons of monazite (66 tons of thorium oxide equivalent) in ore grading 2.8 kilograms per cubic meter. The Mashabuto deposit was reported to contain 45 tons of monazite (3 tons of thorium oxide equivalent) in ore grading 3 kilograms per cubic meter.[19]

**Table 4.—Monazite concentrate: World production, by country[1]**

(Metric tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Australia | 13,282 | 9,562 | 15,141 | 16,702 | 15,000 |
| Brazil | [r]2,460 | [r]1,814 | 5,256 | 3,622 | 6,000 |
| India[e] [3] | [4]3,704 | 4,000 | 4,000 | 4,000 | 4,000 |
| Malaysia[5] | 320 | [r]546 | 1,051 | 4,451 | 6,000 |
| Mozambique | 4 | 3 | 4 | [e]4 | 4 |
| Sri Lanka | 60 | 304 | [e]300 | 147 | 200 |
| Thailand | 107 | 162 | 277 | 298 | 250 |
| United States | W | W | W | W | W |
| Zaire | 35 | 32 | 15 | 2 | -- |
| Total | [r]19,972 | [r]16,423 | 26,044 | 29,226 | 31,454 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Table includes data available through Apr. 29, 1986.

[2]In addition to the countries listed, China, Indonesia, North Korea, the Republic of Korea, Nigeria, and the U.S.S.R. may produce monazite, but output, if any, is not reported quantitatively, and available general information is inadequate for formulation of reliable estimates of output levels.

[3]Data are for years beginning Apr. 1 of that stated.

[4]Reported figure.

[5]The 1981-83 figures are exports and the 1984-85 figures are production.

## TECHNOLOGY

Researchers at the U.S. Geological Survey continued to study data collected on the Atlantic Continental Shelf to delineate the potentially significant concentrations of heavy minerals sands off the coasts of Georgia and Virginia. Initial analyses indicate placer deposits on the Continental Shelf containing from 3% to 10% heavy minerals sands including thorium-containing monazite. Reportedly, the deposits exist at depths accessible by existing mining technology using floating dredges and concentrators.[20]

An updated study on thorium was published by Roskill's Information Services Ltd. The report gives information on the ores, production, consumption, trade, and uses of thorium on a worldwide basis.[21]

Researchers at General Electric Co.'s Research & Development Center at Schenectady, NY, determined that certain ancient thorium-rich and uranium-rich minerals containing long-lived radioactive isotopes apparently self-anneal, thus completely repairing any damage done by radioactive decay in less than 10,000 years. This would include such isotopes as uranium-234 and thorium-230. The long-term effect of radioactive decay in these minerals is reportedly a reduced rate of dissolution in water; consequently, the concern that solidified nuclear waste and other radioactive materials may eventually breakdown by dissolution in water and be leached out may not be valid under certain geoenvironmental conditions.[22]

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[1] Physical scientist, Division of Nonferrous Metals.

[2] Bechtel National Inc., Advanced Technology Div. Radiological Survey of the Albany Research Center, Albany, Oregon. BuMines contract DE-ACO810R20722, Jan. 1985, 75 pp.

[3] The (Portland) Oregonian. New Initiative Takes Aim at Wah Chang Sludge. July 10, 1985.

[4] Free on board-free into container depot.

[5] Values have been converted from Australian dollars (A$) to U.S. dollars (US$) at the exchange rate of A$1.2070=US$1.00 based on yearend 1984 foreign exchange rates published in the Wall Street Journal.

[6] Values have been converted from Australian dollars (A$) to U.S. dollars (US$) at the exchange rate of A$1.4652=US$1.00 based on yearend 1985 foreign exchange rates published in the Wall Street Journal.

[7] Industrial Minerals (London). RGC Increases Offer for Allied Eneabba. No. 219, Dec. 1985, p. 9.

[8] California Mining Journal. Australia To Process Rare Earth Minerals. V. 54, No. 2, Aug. 1985, p. 50.

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[11] Industrial Minerals (London). Australia, $TiO_2$ Corp Launches Mineral Sands Project. No. 217, Oct. 1985, p. 11.

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[13] Mining Journal (London). Bangladesh Beach Sands. V. 305, No. 7841, Nov. 29, 1985, p. 415.

[14] Industrial Minerals (London). Brazil, Rare-Earths Progress. No. 217, Oct. 1985, p. 11.

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[21] Roskill Information Services Ltd. The Economics of Thorium 1985. 4th ed., 1985, 63 pp.

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# Tin

## By James F. Carlin, Jr.[1]

For the fifth consecutive year, there was a substantial world tin excess supply, although world mine production declined and world consumption rose during 1985. In October, the International Tin Council (ITC), which had been buying tin on credit to support the tin price, exhausted its funds for this purpose. This occurrence disrupted the tin industry and caused a suspension of tin from London Metal Exchange (LME) trading for the duration of the year, and tin prices declined markedly during the last 2 months of the year.

**Domestic Data Coverage.**—Domestic production data for tin are developed by the Bureau of Mines from a voluntary survey of U.S. mines. Of the six mines to which a survey form was sent, all responded. Domestic production, which was negligible, was withheld to avoid disclosing company proprietary data.

**Table 1.—Salient tin statistics**

(Metric tons unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production: | | | | | |
| Mine | W | W | W | W | W |
| Smelter | 2,000 | 3,500 | 2,500 | 4,000 | [e]3,000 |
| Secondary | 15,438 | 14,293 | 14,205 | 15,417 | [e]14,911 |
| Exports[1] | 2,361 | 5,769 | 1,340 | 1,429 | 1,478 |
| Imports for consumption: | | | | | |
| Metal | 45,874 | 27,939 | 34,048 | 41,224 | 33,830 |
| Ore (tin content) | 232 | 1,961 | 969 | 3,272 | 1,636 |
| Consumption: | | | | | |
| Primary | 40,229 | 33,019 | 34,301 | 37,819 | 37,136 |
| Secondary | 14,144 | 13,276 | 11,246 | 11,622 | 12,590 |
| Stocks, yearend U.S. industry | 11,131 | 10,251 | 9,859 | 9,977 | 12,363 |
| Prices, average cents per pound: | | | | | |
| New York market | 648.40 | 586.85 | 601.28 | 567.80 | 525.90 |
| Metals Week composite[2] | 733.05 | 653.91 | 654.78 | 623.80 | 595.95 |
| London[2] | 649.53 | 580.50 | 589.19 | 556.55 | 556.26 |
| Kuala Lumpur[2] [3] | 637.85 | 587.29 | 590.78 | 564.95 | 540.70 |
| World: Production: | | | | | |
| Mine | [r]238,008 | [r]219,925 | 196,902 | [p]198,432 | [e]191,103 |
| Smelter | [r]235,931 | [r]221,000 | 199,828 | [p]199,669 | [e]193,715 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; U.S. mine production for 1981-85 was negligible.

[1] Exports (excluding reexports).

[2] Based on 10 months in 1985.

[3] Beginning in 1985, Kuala Lumpur replaced Penang as the reference market.

**Legislation and Government Programs.**—The General Services Administration (GSA) continued its daily fixed-price tin sale program through October when it suspended sales for the balance of the year owing to the ITC disruption, since there was no reliable tin price available. A total of 3,005 metric tons was sold in 1985; of that amount, 2,650 tons represented payment material for GSA's Ferroalloy Upgrading Program, which started April 11, 1984.

At yearend, the National Defense Stockpile inventory was 185,220 tons; the stockpile goal was 42,674 tons.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict that would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, tin would be categorized in tier II with a goal of 150,000 tons, pending Government review. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

The depletion allowance for tin remained at 22% for domestic deposits and 14% for foreign deposits.

## DOMESTIC PRODUCTION

### PRIMARY TIN

**Mine Production.**—Two mines, operating in Alaska and Colorado, produced tin concentrates. Domestic mine production data were withheld to avoid disclosing company proprietary data, but total output amounted to only a small fraction of domestic tin requirements.

**Smelter Production.**—The only domestic tin smelter, Tex Tin Corp., in Texas City, TX, and owned by Gulf Chemical & Metallurgical Corp., a subsidiary of Associated Metals & Minerals Corp., decreased tin metal output to an estimated 3,000 tons. The smelter treated imported and domestic concentrates, secondary tin-bearing materials, and its own stockpile of tin residues and slags. The smelter's major source of tin concentrates was Peru. In August, Tex Tin announced it was ceasing production of refined tin for the balance of the year.

### SECONDARY TIN

The United States was believed to be the world's largest producer of secondary tin. Secondary tin from recycled fabricated parts was an important source of material for the solder and the brass and bronze industries.

**Table 2.—Secondary tin recovered from scrap processed at detinning plants in the United States**

| | 1984 | 1985 |
|---|---|---|
| Tinplate scrap treated metric tons | 492,825 | 460,105 |
| Tin recovered in the form of: | | |
| Metal do | 824 | 931 |
| Compounds (tin content) do | 301 | 186 |
| Total[1] do | 1,125 | 1,117 |
| Weight of tin compounds produced do | 1,498 | 398 |
| Average quantity of tin recovered per metric ton of tinplate scrap used kilograms | 2.24 | 2.38 |
| Average delivered cost of tinplate scrap per metric ton | $68.01 | $53.69 |

[1] Recovery from tinplate scrap treated only. In addition, detinners recovered 366 metric tons of tin as metal and in compounds from tin-base scrap and residues in 1985.

### Table 3.—Tin recovered from scrap processed in the United States, by form of recovery

(Metric tons unless otherwise specified)

| Form of recovery | 1984 | 1985 |
|---|---|---|
| **Tin metal:** | | |
| At detinning plants | 1,097 | 1,292 |
| At other plants | 10 | 10 |
| Total | 1,107 | 1,302 |
| **Bronze and brass:** | | |
| From copper-base scrap | 9,071 | [e]8,800 |
| From lead- and tin-base scrap | 75 | 47 |
| Total | 9,146 | [e]8,847 |
| Solder | 3,653 | 3,565 |
| Type metal | 142 | 122 |
| Babbitt | 123 | 88 |
| Antimonial lead | 894 | 791 |
| Chemical compounds | 301 | 186 |
| Miscellaneous[1] | 51 | 10 |
| Total | 5,164 | 4,762 |
| Grand total | 15,417 | [e]14,911 |
| Value (thousands)[2] | [r]$212,021 | [e]$195,907 |

[e] Estimated. [r] Revised.
[1] Includes foil and terne metal.
[2] Based on Metals Week composite price.

## CONSUMPTION AND USES

Primary tin consumption remained about the same as that of 1984, and was well below the levels of the 1970's. Solder was the largest application of primary tin, with tinplate a distant second.

Tinplate continued to lose markets to aluminum in container applications. Of the 101.9 billion metal cans shipped, tinplated steel and tin-free steel accounted for 34% and aluminum accounted for 66%, compared with 97.8 billion metal cans shipped in 1984, when steel accounted for 35% and aluminum for 65%. Aluminum held an overwhelming segment of the beverage can market, while steel was still predominant in the food can and the general packaging markets.[2]

### Table 4.—U.S. consumption of primary and secondary tin

(Metric tons)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Stocks, Jan. 1[1] | 8,835 | 8,717 | 7,549 | 7,740 | 8,478 |
| **Net receipts during year:** | | | | | |
| Primary | 41,162 | 35,843 | 36,494 | 39,388 | 38,936 |
| Secondary | 5,692 | 6,507 | 5,412 | 6,096 | 8,904 |
| Scrap | 8,050 | 7,830 | 7,435 | 7,323 | 7,917 |
| Total receipts | 54,904 | 50,180 | 49,341 | 52,807 | 55,757 |
| Total available | 63,739 | 58,897 | 56,890 | 60,547 | 64,235 |
| **Tin consumed in manufactured products:** | | | | | |
| Primary | 40,229 | 33,019 | 34,301 | 37,819 | 37,136 |
| Secondary | 14,144 | 13,276 | 11,246 | 11,622 | 12,590 |
| Total | 54,373 | 46,295 | 45,547 | 49,441 | 49,726 |
| Intercompany transactions in scrap | 726 | 274 | 245 | 318 | 214 |
| Total processed | 55,099 | 46,569 | 45,792 | 49,759 | 49,940 |
| Stocks, Dec. 31 (total available less total processed) | 8,640 | 12,328 | 11,098 | 10,788 | 14,295 |

[1] Includes tin in transit in the United States.

## Table 5.—Tin content of tinplate produced in the United States

| Year | Tinplate waste (waste, strips, cobbles, etc., gross weight) (metric tons) | Tinplate (all forms) | | |
|---|---|---|---|---|
| | | Gross weight (metric tons) | Tin content[1] (metric tons) | Tin per metric ton of plate (kilograms) |
| 1981 | 284,505 | 3,288,662 | 13,306 | 4.0 |
| 1982 | 208,074 | 2,712,678 | 10,936 | 4.0 |
| 1983 | 166,186 | 2,586,810 | 9,328 | 3.6 |
| 1984 | 152,093 | 2,500,945 | 8,659 | 3.5 |
| 1985 | 146,041 | 2,215,042 | 9,322 | 4.2 |

[1] Includes [illegible] of secondary tin and tin acquired in chemicals.

## Table 6.—U.S. consumption of tin, by finished product

(Metric tons of contained tin)

| Product | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Primary | Secondary | Total | Primary | Secondary | Total |
| Alloys (miscellaneous)[1] | W | W | W | W | W | W |
| Babbitt | 2,343 | 341 | 2,684 | 1,147 | 341 | 1,488 |
| Bar tin | 522 | 4 | 526 | 466 | W | 466 |
| Bronze and brass | 1,686 | 3,312 | 4,998 | 1,672 | 2,657 | 4,329 |
| Chemicals | W | W | W | W | W | W |
| Collapsible tubes and foil | W | W | W | W | W | W |
| Solder | 13,450 | 3,799 | 17,249 | 13,301 | 5,315 | 18,616 |
| Tinning | 1,748 | W | 1,748 | 1,511 | W | 1,511 |
| Tinplate[2] | 8,659 | 166 | 8,825 | 9,322 | W | 9,322 |
| Tin powder | 1,057 | W | 1,057 | 977 | W | 977 |
| Type metal | W | W | W | 7 | W | 7 |
| White metal[3] | 881 | 77 | 958 | 876 | 61 | 937 |
| Other | 7,473 | 3,923 | 11,396 | 7,857 | 4,216 | 12,073 |
| Total | 37,819 | 11,622 | 49,441 | 37,136 | 12,590 | 49,726 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes terne metal.

[2] Includes secondary pig tin and tin acquired in chemicals.

[3] Includes pewter, britannia metal, and jewelers' metal.

## Table 7.—U.S. industry yearend tin stocks

(Metric tons)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Plant raw materials: | | | | | |
| Pig tin: | | | | | |
| Virgin[1] | 6,857 | 6,269 | 6,326 | 5,480 | 5,731 |
| Secondary | 411 | 265 | 732 | 1,562 | 2,342 |
| In process[2] | 1,449 | 1,015 | 682 | 1,164 | 1,367 |
| Total | 8,717 | 7,549 | 7,740 | 8,206 | 9,440 |
| Additional pig tin: | | | | | |
| Jobbers-importers | 1,943 | 1,386 | 608 | 761 | 1,642 |
| Afloat to United States | 471 | 1,316 | 1,511 | 1,010 | 1,281 |
| Total | 2,414 | 2,702 | 2,119 | 1,771 | 2,923 |
| Grand total | 11,131 | 10,251 | 9,859 | 9,977 | 12,363 |

[1] Includes tin in transit in the United States.

[2] Data represent scrap only, tin content.

## PRICES

The price of tin metal remained relatively flat during the first 10 months of 1985, at about $6 per pound, as published in Metals Week. However, when the ITC exhausted funds to support the tin price in October and the LME consequently suspended tin trading for the duration of the year, there were no reliable benchmarks to evaluate the tin price. Sporadic price quotations, as published in Metals Week, during November and December, from New York and Asian markets, indicated a price of about $3.50 per pound.

**Table 8.—Monthly composite price of Straits tin for delivery in New York**

(Cents per pound)

| Month | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | High | Low | Average | High | Low | Average |
| January | 625.60 | 622.20 | 623.74 | 586.44 | 566.26 | 573.67 |
| February | 634.77 | 622.13 | 627.88 | 568.27 | 552.37 | 562.62 |
| March | 644.90 | 627.36 | 626.65 | 592.27 | 553.49 | 565.68 |
| April | 638.71 | 633.65 | 636.50 | 612.58 | 569.33 | 591.56 |
| May | 641.05 | 632.36 | 636.32 | 601.38 | 561.43 | 588.61 |
| June | 640.12 | 635.21 | 638.25 | 613.74 | 597.34 | 604.03 |
| July | 635.10 | 624.86 | 629.89 | 637.77 | 610.51 | 626.31 |
| August | 632.50 | 619.23 | 626.00 | 631.25 | 617.73 | 626.49 |
| September | 623.70 | 607.27 | 618.08 | 627.36 | 592.91 | 610.07 |
| October | 607.49 | 597.45 | 603.61 | 614.88 | 605.61 | 610.46 |
| November | 615.98 | 600.82 | 609.94 | NA | NA | NA |
| December | 604.30 | 591.88 | 598.76 | NA | NA | NA |
| Average[1] | XX | XX | 623.80 | XX | XX | 595.95 |

NA Not available. XX Not applicable.

[1] Based on 10 months in 1985.

Source: Metals Week.

## FOREIGN TRADE

Imports of tin concentrates in 1985 declined sharply, indicating the reduced level of activity at the Tex Tin smelter.

Imports of tin metal declined, with Brazil remaining the major source, followed by Thailand, Indonesia, and China. China has emerged in recent years as an important supplier.

Imports of tin in all forms (ore and concentrate, metal, and waste and scrap) remained free of U.S. duty.

**Table 9.—U.S. imports for consumption and exports of miscellaneous tin, tin manufactures, and tin compounds**

| Year | Miscellaneous tin and tin manufactures | | | | Tin compounds | |
|---|---|---|---|---|---|---|
| | Imports | | | Exports | Imports | |
| | Tinfoil, tin powder, flitters, metallics, tin and manufactures, n.s.p.f. | Dross, skimmings, scrap, residues, tin alloys, n.s.p.f. | | Tin scrap and other tin-bearing material, except tinplate scrap | Quantity (metric tons) | Value (thousands) |
| | Value (thousands) | Quantity (metric tons) | Value (thousands) | Value (thousands) | | |
| 1983 | $10,728 | 1,193 | $1,219 | $8,972 | 642 | $4,120 |
| 1984 | 3,292 | 1,211 | 1,318 | 12,494 | 838 | 5,301 |
| 1985 | 3,290 | 877 | 2,804 | 18,357 | 827 | 5,164 |

Source: Bureau of the Census.

## Table 10.—U.S. exports and imports for consumption of tin, tinplate, and terneplate in various forms; exports of ingots, pigs, bars; imports of tinplate scrap

| Year | Ingots, pigs, bars | | Tinplate and terneplate | | | | Tinplate scrap | |
|---|---|---|---|---|---|---|---|---|
| | Exports | | Exports[1] | | Imports | | Imports | |
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1983 | 1,340 | $17,305 | 171,121 | $83,827 | 266,548 | $168,413 | 2,144 | $188 |
| 1984 | 1,429 | 14,409 | 154,679 | 93,033 | 338,630 | 203,147 | 4,755 | 480 |
| 1985 | 1,478 | 16,744 | 155,119 | 85,000 | 381,137 | 222,504 | 3,815 | 441 |

[1] Tinplate circles, strips, and cobbles are included with exports of tinplate and terneplate.

Source: Bureau of the Census.

## Table 11.—U.S. imports for consumption of tin, by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Concentrates (tin content): | | | | |
| Australia | -- | -- | (1) | $22 |
| Bolivia | 271 | $1,782 | 22 | 97 |
| Canada | 1 | 1 | 24 | 102 |
| Mexico | 17 | 78 | 32 | 102 |
| Peru | 2,502 | 14,308 | 1,506 | 9,966 |
| Singapore | 46 | 475 | -- | -- |
| South Africa, Republic of | 3 | 28 | 32 | 351 |
| Thailand | 403 | 3,883 | 20 | 19 |
| Zaire | 29 | 306 | -- | -- |
| Total[2] | 3,272 | 20,862 | 1,636 | 10,659 |
| Metal:[3] | | | | |
| Australia | 288 | 4,179 | 266 | 3,060 |
| Belgium-Luxembourg | 137 | 1,688 | -- | -- |
| Bolivia | 5,438 | 67,742 | 1,815 | 21,187 |
| Brazil | 10,220 | 126,190 | 11,021 | 127,128 |
| Burma | 64 | 776 | -- | -- |
| Canada | 8 | 66 | 18 | 233 |
| Chad | -- | -- | 20 | 245 |
| Chile | 218 | 3,713 | 673 | 7,392 |
| China | 1,640 | 20,596 | 4,513 | 60,126 |
| Denmark | 40 | 489 | -- | -- |
| France | -- | -- | 167 | 1,803 |
| Germany, Federal Republic of | r(1) | 11 | 147 | 1,574 |
| Hong Kong | -- | -- | 258 | 2,954 |
| India | -- | -- | 450 | 5,012 |
| Indonesia | 4,985 | 62,224 | 4,586 | 53,753 |
| Japan | 20 | 242 | 188 | 2,131 |
| Korea, Republic of | -- | -- | 3 | 41 |
| Malaysia | 6,622 | 80,546 | 379 | 4,503 |
| Netherlands | 140 | 1,743 | 45 | 499 |
| Nigeria | 60 | 788 | -- | -- |
| Norway | -- | -- | 149 | 1,838 |
| Paraguay | 1 | 6 | -- | -- |
| Philippines | 20 | r258 | -- | -- |
| Rwanda | 30 | 367 | -- | -- |
| Singapore | 781 | 4,128 | 1,886 | 22,156 |
| South Africa, Republic of | 10 | 121 | 105 | 1,282 |
| Sweden | -- | -- | 280 | 2,948 |
| Switzerland | -- | -- | 50 | 589 |
| Taiwan | -- | -- | 120 | 1,423 |
| Thailand | 9,531 | 104,657 | 6,373 | 75,123 |
| United Arab Emirates | -- | -- | 129 | 1,225 |
| United Kingdom | 583 | 7,253 | 48 | 606 |
| Zaire | 89 | 787 | -- | -- |
| Zimbabwe | 296 | 3,462 | 140 | 1,283 |
| Total[2] | 41,224 | 492,030 | 33,830 | 400,405 |

r Revised.

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

[3] Bars, blocks, pigs, or granulated.

Source: Bureau of the Census.

## WORLD REVIEW

**International Tin Agreement.**—The Sixth International Tin Agreement (ITA), which commenced on July 1, 1982, continued in effect throughout 1985. The United States was not a member of the agreement.

The ITC continued to be heavily engaged in tin price support actions for most of the year to defend the ITC's floor price by buying tin for its stockpile. The ITC retained the same buffer stock floor price of 29.15 Malaysian dollars (M$) per kilogram and the ceiling price of M$37.89 that were in effect since October 17, 1981. On October 24, 1985, the ITC exhausted funds to support the tin price. This caused severe disruption of the world tin market. The LME and the Kuala Lumpur Tin Market immediately suspended tin trading while the ITC tried to reach financial settlements for debts owed to banks and trading firms for past tin purchases, and while the ITC attempted to reestablish its tin price support program. In the final months of the year, various proposals were considered to enable the ITC to refinance its large debt, but the ITC could not reach agreement among its 22-nation member governments on any plan, and the year ended with the matter unresolved.

Throughout the year, the ITC continued to maintain export controls on producer member countries at a level of 39.6% of the levels of tin exports prevailing before July 1, 1982, which was the commencement date for the export control program. Despite the existence of export controls for over 3 years, industry sources estimated the world tin surplus at about 70,000 tons at yearend 1985.

Tin smuggling in Southeast Asia continued to be a problem, although it declined at yearend with the sharp drop in tin prices. Tin smuggling was counterproductive to export control measures and was viewed as a significant factor in contributing to the world tin surplus. Industry sources indicated that Singapore continued to be the destination for considerable tonnage of smuggled tin concentrates from Indonesia, Malaysia, and Thailand.

The Association of Tin Producing Countries (ATPC), comprised of seven major producer nations—Australia, Bolivia, Indonesia, Malaysia, Nigeria, Thailand, and Zaire—completed its second year as an organization. ATPC viewed itself as being complementary to, and supportive of, the activities of the ITC, and the organization attempted to persuade non-ITA member countries to restrain tin production.

**Australia.**—Aberfoyle Ltd. announced plans to halt tin production at its Ardlethan Mine in New South Wales. In recent years, mining at Ardlethan had been mostly from remnant areas that had raised the cost of production. Aberfoyle attributed the closure to depletion of reserves and to the sharp decline in tin prices that occurred late in 1985. Tasmania was the source of about two-thirds of Australia's tin production. The large Renison underground tin mine in western Tasmania accounted for about 40% of the country's total output of tin.

Domestic tin usage was estimated at 2,500 tons, with the tinplate industry being the largest consumer.

There were two primary tin refineries. The Associated Tin Smelters Pty. Ltd. (ATS) in Sydney, which was the larger of the two, obtained its tin concentrate from producers in eastern Australia, including Queensland and New South Wales. The other refinery was operated by Greenbushes Tin Ltd. in Western Australia and smelted the production from its own tin-tantalum mine.

**Bolivia.**—The Corporación Minera de Bolivia (COMIBOL) was the country's largest tin producer. A significant proportion of mine output was from medium-sized mines. There were also many small mines and some mining cooperatives. The three largest mines were the Huanuni, the La Palca, and the Catavi. Bolivia remained a high-cost tin producer, largely because its mines were the hard-rock underground type and its tin deposits were of relatively low grade. Most of the tin concentrates produced were beneficiated in mills adjoining the mines.

Strikes continued to hamper various production sites throughout the year. The European Economic Community (EEC) displaced the United States as the largest single customer for Bolivian tin.

**Brazil.**—Brazil was not a member of the ITA and therefore not bound by the ITA's export controls, and Brazilian tin mines significantly increased their output, as they have done in recent years. Brazil ranked as the world's fifth largest tin producer. The three leading private tin mining companies in Brazil were Paranapanema S.A. Mineração, Indústria e Construção, Brascan Recursos Naturais S.A. (BRN), and Mineração Brumadinho S.A.

The leading producer, Paranapanema, accounted for more than one-half of Brazil's total output, operating at least seven tin mines. Paranapanema reported sharply increased output from its new Pitinga operations in the Mapuere region in Amazonas State. The company shipped the entire output of its mines to its Mamoré smelter, near São Paulo, for conversion to refined metal.

BRN, jointly owned by Brascan Ltd. and BP Mineração, was Brazil's second leading tin producer. It operated several mines, all in the State of Rondônia. BRN's tin concentrates were shipped to its Cesbra smelter for refining.

Brumadinho, the third largest tin producer, operated several alluvial tin mines in Rondônia and explored several tin properties in Goiás State. Brumadinho shipped all its tin concentrates to the tin smelter Bera do Brasil S.A., near São Paulo. Bera was 70% owned by Brumadinho and 30% by Paul Bergsoe and Son A/S of Denmark.

St. Joe Minerals Corp. commenced production at its Mocambo Mine, an alluvial deposit situated near São Felix in the Xingu River area of Pará State. Production from the high-grade deposit was expected to be about 1,000 tons per year.

Constructora Andrade Gutierrez S.A. started tin production at its Itaiutuba Mine in Pará State. The firm expected to produce about 500 tons of tin annually.

Canopus S.A. started tin production at its Rhodia-Espeng alluvial tin deposit located in the Iriri River region of Pará State. Production was expected to be about 800 tons per year of tin.

There were at least 10 tin smelters in Brazil, but none, except Mamoré, had sufficient feed to operate at designed capacity.

**Canada.**—Late in 1985, Rio Algom Ltd. started production at its large open pit tin mine at East Kemptville, Nova Scotia. The operation was expected to produce about 4,500 tons per year of tin concentrate, and rank as the largest tin mine in North America. All tin concentrates were shipped to the Capper Pass tin smelter in North Ferriby, the United Kingdom.

Lac Minerals Ltd. announced the start of a 1-year evaluation project on the Mount Pleasant, New Brunswick tin property owned by Billiton Canada Ltd.

**China.**—Plans were announced by the Yunnan Provincial government to construct the Wenshan tin complex with the capacity to mine and smelt 3,000 tons of refined tin annually.

Technomin Australia NL formed a joint venture with the Chinese Government's National Nonferrous Metals Industry Corp. to prospect for tin in China. Initial plans were to investigate areas near the recently developed DaChang tin mine, which reported tin grades of almost 1%.

A new tin smelter at Liepan in Guangxi Province was reportedly near completion, with expected annual capacity of about 8,000 tons of refined tin.

**India.**—India's Mineral Exploration Corp. (MEC) reported the discovery of a tin deposit at Tosham in Haryana Province. Tin grades were about 0.10%. Plans were announced to construct a tinplate facility near the Port of Goa. The London-based Caparo Group Ltd. was expected to provide financing.

**Indonesia.**—Tin deposits were primarily offshore. P.T. Tambang Timah (P.T. Timah), the national mining firm, was the major producer. P.T. Koba Tin was the second largest producer, with its largest mine situated on Bangka Island. Koba was jointly owned by Kajaura Mining Corp. (Pty.) Ltd., an Australian company, and by P.T. Timah.

Preussag AG (Federal Republic of Germany) purchased the Kelapa Kampit tin mine from The Broken Hill Pty. Co. Ltd. (Australia).

The new P.T. Latinusa electrolytic tinning line facility in Cilegon, West Java, began production. The plant was a joint venture of P.T. Timah and P.T. Krakatan Steel, both Government-owned, and P.T. Nusamba, a local firm. The facility was expected to reach full capacity of 130,000 tons per year of tinplate in 1988 and to raise domestic tin ore consumption to 10% of the country's output.

**Malaysia.**—Although Malaysia remained the world's leading tin producer, its tin mining activities continued the pattern of decline of recent years. There were 465 mines in 1985, compared with 852 in 1980. The number of dredges declined from 54 in 1980 to 25 in 1985, and the labor force declined from 39,000 people in 1980 to 22,000 in 1985.

Two large smelters continued operating at Penang, refining all of Malaysia's tin concentrates and considerable amounts of imported concentrates. The Malaysia Mining Corp. closed its New York, NY, sales office because of the low level of tin exports to the United States. The major destination for exported tin was Japan, followed by the EEC.

**Mexico.**—Mexican tin mining occurred sporadically in the three adjoining States of Durango, Zacatecas, and San Luis Potosí in the north-central part of the country. Cía Minera Pizzuto owned Mexico's main tin mine, the El Perro Mine, in San Luis Potosí. The country's main tin smelter was operated by Estāno Electro S.A. de C.V. at Tlalnepantla, near Mexico City, with a capacity of 1,200 tons of refined tin annually. Fundidora de Estāno S.A. operated a tin smelter at San Luis Potosí with a 1,200-ton annual capacity. Both smelters treated mainly imported tin concentrates.

**Nigeria.**—Five firms mined tin: Amalgamated Tin Mines of Nigeria (Holdings) Ltd., Bisichi-Jantar Nigeria Ltd., Kaduna Prospecting Nigeria Ltd., Ex-Lands Nigeria Ltd., and Gold & Base Metal Mines of Nigeria Ltd. All tin concentrates were smelted domestically by Makeri Smelting Co. Ltd.

**Peru.**—Tin mine output continued the pattern of steady increases of recent years, and Peru maintained its position as the major supplier of tin concentrates to the United States. The San Rafael Mine, owned by Minsur S.A., was the only tin mine. Situated near Juliaca, the mine was within the northern extension of the Bolivian tin belt. The mine reported tin grades of 1.8%.

**South Africa, Republic of.**—Gold Fields of South Africa Ltd. was the parent firm of two moderate-sized tin producers, Rooiberg Tin Ltd. and Union Tin Mines Ltd. Both firms reported declining ore grades, currently about 0.4% tin. Zaaiplaats Tin Mining Co. Ltd. was also a producer.

**Thailand.**—Billiton Thailand Ltd., owned by the Royal Dutch/Shell Group's Billiton B.V., closed its 10-year-old tin dredging operation at midyear. The firm cited dwindling tin reserves in its Government-owned concession block along Thailand's southern coastline and the Government's refusal to grant it new acreage as the reasons for the closure. In recent years, this operation produced about 1,300 tons of tin concentrates annually. Near yearend, the firm considered a proposal from former employees of the defunct operation to purchase it and restart production with the aid of public capitalization.

Throughout the year, Thai miners protested various Government policies, including the high tin royalty system. In response, the Government suspended the issuance of any new tin mining licenses or concessions to lessen competition and reduced some fees and operational charges to aid the miners.

The country's newest smelter, Siam Charoen Tin Smelting Co. expected to start production during the year. Situated near Bangkok, the plant had an expected 360-ton-per-year capacity to supply the domestic solder, pewter, and bronze market. Thai Pioneer Enterprise Co. Ltd., which closed its 3,600-ton-per-year tin smelter in 1982, was negotiating for financing throughout the year, trying to reopen the smelter. The Thailand Smelting and Refining Co. Ltd., a Billiton subsidiary, operated the country's largest tin smelter, at Phuket, with a 38,000-ton-per-year refined tin capacity. Smuggling continued to be a problem, especially in the Andaman Sea region. The Thai Mining Industry Council estimated that 7,000 tons of tin concentrates were smuggled from the country in 1985. The Government introduced several new antismuggling regulations.

**U.S.S.R.**—Tin was one of only a few major metals for which the Soviet Union was significantly dependent on imports, although it was an important producer. Tin mining was concentrated in remote eastern parts of the country. The Deputatskiy tin mining and benefication complex in Yakutia was scheduled to commission the first stage of a lode mine and concentrator in the 1986-90 period. In Soviet Central Asia, development of the Sary Ozhaz tin mining complex in Kirgiziya was scheduled for the 1986-90 period.

**United Kingdom.**—The Rio Tinto Zinc Corp. PLC (RTZ) controlled about 80% of the United Kingdom's tin output through its ownership of the Wheal Jane and the South Crofty Mines in Cornwall. A third major producer, Geevor Tin Mines Ltd., also operated a lode mine in Cornwall. Despite optimistic plans during most of the year to expand and modernize these three old mines, the tin price collapse near yearend made the continued survival of these three high-cost mines questionable.

**Zaire.**—The major tin producer was Société Minière et Industrielle de Kivu (Sominki) in Kivu. The company was 28% Government-owned and 72% owned by Empain-Schneider Group of France. Tin concentrates were shipped to Europe for smelting. The second largest producer was Société Zairetain, with 50% Government ownership and 50% ownership by Geomines Cie. of Belgium. The third largest producer was Société Minière de Goma (SMOG) 20% Government-owned and 80% owned by the Bureau de Recherches Géologiques et Minières.

## Table 12.—Tin: World mine production, by country[1]

(Metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina | 413 | 304 | 291 | 274 | 270 |
| Australia | 12,267 | 12,126 | [3]9,275 | 7,699 | 7,000 |
| Bolivia | 29,830 | 26,773 | 25,278 | 19,911 | 18,000 |
| Brazil | [r]8,297 | [r]8,218 | 13,275 | 19,957 | 22,000 |
| Burma | 1,438 | 1,681 | 1,642 | 2,028 | [3]1,751 |
| Cameroon | [r]21 | 15 | ([4]) | 14 | 15 |
| Canada | 239 | 135 | 141 | 217 | 250 |
| China[e] | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 |
| Czechoslovakia[e] | [r]300 | [r]200 | [r]250 | [r]250 | 250 |
| German Democratic Republic[e] | 1,600 | 1,700 | 1,800 | 1,800 | 1,800 |
| Indonesia | 35,392 | 33,806 | 26,553 | 23,223 | [3]22,115 |
| Japan | 561 | 529 | 600 | 485 | [3]510 |
| Korea, Republic of | -- | -- | -- | 19 | -- |
| Laos | 255 | 302 | 359 | 430 | 540 |
| Malaysia | 59,938 | 52,342 | 41,367 | 41,307 | [3]36,884 |
| Mexico | 28 | 27 | 334 | 416 | 400 |
| Namibia | 1,228 | 1,326 | [e]1,400 | 906 | [3]987 |
| Niger | 55 | 36 | 40 | 76 | 50 |
| Nigeria | 3,172 | 2,355 | 1,560 | 1,700 | 1,700 |
| Peru | 1,519 | 1,672 | 2,368 | 2,991 | [3]3,807 |
| Portugal | 506 | 410 | 347 | [e]350 | 360 |
| Rwanda | 1,790 | 1,655 | 1,526 | 1,561 | 1,200 |
| South Africa, Republic of | 2,811 | 3,035 | 2,668 | 2,301 | [3]2,194 |
| Spain | 564 | 518 | 444 | 438 | [3]465 |
| Tanzania | 9 | 9 | 6 | [r] [e]6 | 6 |
| Thailand | 31,474 | 26,109 | 19,943 | 21,920 | 20,000 |
| Uganda | ([5]) | [r]4 | [r]25 | [r]25 | 25 |
| U.S.S.R.[e] | [r]21,000 | [r]21,000 | [r]22,000 | [r]23,000 | 23,000 |
| United Kingdom | 3,869 | 4,208 | 4,025 | 5,216 | 5,300 |
| United States | W | W | W | W | W |
| Vietnam[e] | [3]380 | [r]500 | 550 | 500 | 600 |
| Zaire[6] | [r]2,452 | [r]2,320 | 2,163 | 2,708 | 2,870 |
| Zambia[e] | -- | 10 | 22 | [3]4 | 4 |
| Zimbabwe[e] | 1,600 | 1,600 | 1,650 | 1,700 | 1,750 |
| Total | [r]238,008 | [r]219,925 | 196,902 | 198,432 | 191,103 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Contained tin basis. Data derived in part from the Monthly Statistical Bulletin of the International Tin Council, London. Table includes data available through June 17, 1986.

[2]Excludes tin content of copper-tin cathodes.

[3]Reported figure.

[4]Revised to "Not available" as available general information is inadequate to determine a reliable estimate of output level, if any.

[5]Revised to zero.

[6]Nonduplicated total of content of concentrate plus smelter production.

## Table 13.—Tin: World smelter production, by country[1]

(Metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina[e] | 200 | 200 | [r]200 | [r]200 | 200 |
| Australia | 4,286 | 3,105 | 2,913 | 2,899 | [3]2,653 |
| Belgium | 65 | -- | -- | -- | -- |
| Bolivia | 20,005 | 19,032 | 14,164 | 15,842 | 12,000 |
| Brazil | 7,789 | 9,298 | 12,950 | 18,887 | 21,000 |
| China[e] | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 |
| Czechoslovakia[3] | 289 | 295 | 307 | 425 | 430 |
| German Democratic Republic[e] | [r]1,500 | 2,000 | 2,000 | 2,000 | 2,000 |
| Germany, Federal Republic of | 1,815 | 608 | 417 | [e]400 | 400 |
| Indonesia | 32,519 | 29,755 | 28,390 | 22,467 | 21,200 |
| Japan | 1,315 | 1,296 | 1,260 | 1,354 | [3]1,391 |
| Malaysia[4] | 70,326 | 62,836 | 53,338 | 46,911 | 47,000 |
| Mexico[5] | 838 | 944 | 1,216 | 1,531 | 1,500 |
| Netherlands | 3,500 | 2,800 | 5,398 | 6,517 | 5,500 |
| Nigeria | 2,486 | 2,754 | 1,190 | [e]1,300 | 1,400 |
| Portugal | 900 | 400 | 200 | [e]180 | 200 |
| Rwanda | -- | 908 | 1,110 | [r] [e]1,000 | 900 |
| South Africa, Republic of | 2,602 | 2,884 | 2,685 | 1,592 | [3]1,366 |
| Spain | 4,400 | 3,700 | 3,700 | 3,500 | 3,500 |
| Thailand | 32,626 | 25,497 | 18,467 | 19,979 | 19,000 |

See footnotes at end of table.

**Table 13.—Tin: World smelter production, by country[1] —Continued**

(Metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| U.S.S.R.[e] | [r]23,000 | [r]24,000 | [r]24,000 | [r]25,000 | 25,000 |
| United Kingdom | [r]6,863 | [r]8,164 | 6,467 | 6,830 | 7,200 |
| United States[6] | 2,000 | 3,500 | 2,500 | 4,000 | 3,000 |
| Vietnam | -- | [e]475 | 520 | [e]475 | 570 |
| Zaire | 450 | 352 | 201 | 170 | 150 |
| Zimbabwe | 1,157 | 1,197 | 1,235 | 1,210 | 1,225 |
| Total | [r]235,931 | [r]221,000 | 199,828 | 199,669 | 193,715 |

[e] Estimated. [p] Preliminary. [r] Revised.

[1] Data derived in part from the Monthly Statistical Bulletin of the International Tin Council, London. Output reported throughout is primary tin only unless otherwise specified. Table includes data available through June 17, 1986.

[2] Reported figure.

[3] May include secondary tin.

[4] Includes small production of tin from smelter in Singapore.

[5] Primarily from imported tin concentrate.

[6] Includes tin content of alloys made directly from ores.

## TECHNOLOGY

Advances continued to be made in high-speed, high-quality wave soldering techniques and machinery to meet the rapidly changing needs of the printed circuit board industry. Wave soldering involved carriage of the printed circuit board by linear conveyor through a fluxing stage to ensure solder wetting, a preheating stage to evaporate flux solvent and lessen subsequent thermal shock, and a soldering stage where the board passes over a molten solder wave made by continuously pumping solder up through a slot. Most recent developments occurred in Europe. A significant innovation was the development of a machine that permitted wave soldering of surface-mounted components fixed to the underside of a printed circuit board, by double wave systems.[3]

Because of concerns about the harmful effects of lead, lead-free solders have become increasingly used, especially for plumbing applications. These solders were generally tin-rich solders, such as 97% tin-3% copper or 97% tin-3% silver, utilized as capillary plumbing solders. Studies by the British Association for Brazing and Soldering illustrated that capillary plumbing joint strengths of lead-free solders at ambient temperatures and at 100° C are equal to or greater than those of leaded solders.[4]

A new compact machine was developed that used centrifugal force in combination with room-temperature vulcanizing silicones to create a combination mold making and casting machine. The machine could encourage growth of pewter usage.[5]

The industrial use of sintered stainless steel reportedly was restricted by the poor corrosion resistance of the materials in comparison to the wrought counterpart. A new alloy was developed that utilized 304-L stainless steel powder with additions of either 2% tin or 2% nickel plus 2% copper plus 1% tin. The resulting alloy exhibited significantly improved corrosion resistance.[6]

A technique of electrolytic bronzing of aluminum was developed that used tin electrolytes. The process was reportedly providing harder anodic films and less spalling than conventional bronzing methods.[7]

There are many applications requiring a fast, efficient method of joining copper conductors. A machine was developed to join insulated magnet wire to tinned wire and required no prior removal of the wire's insulation or additional filler metals to form a valid joint.[8]

In the field of tin-canned foods, a new procedure was found to expedite processing. High vacuum flame sterilization of particulate foods was a high temperature, quick-processing method that rolled preheated canned products on tracks over gas burners. Results claimed include better retention of original product quality, providing canned fruits and vegetables with color, taste, and texture very close to those of fresh. In addition, omission of most or all of the traditional covering liquid reduced pack weight, and thus ultimately could lead to smaller cans.[9]

Also in the field of tin cans, a processing innovation called Pressure Fresh was announced. This was a system that combined deoxygenation in the can with the injection of liquid nitrogen to extend shelf life and preserve color and flavor of canned juices. In the process, oxygen levels were reduced from 9 parts per million to less than 1 part per million, and eventually could eliminate the need for tin coating the inside of citrus juice containers.[10]

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[1] Physical scientist, Division of Nonferrous Metals.

[2] Can Manufacturer's Institute. Metal Can Shipments Report 1985. Washington, DC, 1985, p. 3.

[3] Tin and Its Uses. No. 148, 1986, pp. 4-9.

[4] Pages 13-15 of work cited in footnote 3.

[5] Pages 15-17 of work cited in footnote 3.

[6] Page 17 of work cited in footnote 3.

[7] Tin and Its Uses. No. 146, 1985, pp. 10-13.

[8] ———. No. 145, 1985, pp. 15-16.

[9] Tin News. Tin-Novations. V. 34, No. 7, July 15, 1985, p. 4.

[10] Work cited in footnote 9.

# Titanium

## By Langtry E. Lynd[1] and Ruth A. Hough[2]

Domestic production of ilmenite, rutile, and synthetic rutile increased in 1985. Consumption of titanium concentrates also increased, and production and consumption of titanium dioxide ($TiO_2$) pigment reached new record-high levels, reflecting continued strength in the homebuilding industry. Domestic production and consumption of titanium sponge and ingot declined somewhat, but net shipments of mill products were up slightly. During the year, there were a number of changes and proposed changes in the ownership of domestic sponge metal producers. Prices of titanium concentrates generally increased because of the high demand for $TiO_2$ pigment. Titanium sponge metal prices were lower because of relatively low demand and the availability of considerable excess production capacity in both the United States and Japan. Titanium dioxide pigment prices increased, reaching new high levels by yearend.

**Domestic Data Coverage.**—Consumption data for titanium raw materials are developed by the Bureau of Mines from a voluntary domestic survey. Of the 38 operations to which a survey request was sent, 95% responded, representing 99.86% of the consumption of ilmenite, rutile, and titanium slag shown in tables 1 and 7. Consumption for the two nonrespondents was estimated using reported prior year consumption levels.

**Table 1.—Salient titanium statistics**

(Short tons unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| **United States:** | | | | | |
| Ilmenite concentrate: | | | | | |
| Mine shipments | 523,681 | 233,063 | W | W | W |
| Value thousands | $37,013 | $19,093 | W | W | W |
| Imports for consumption | 236,217 | 348,366 | 259,328 | 409,605 | 506,804 |
| Consumption | 856,116 | 583,250 | 730,578 | 783,391 | 756,071 |
| Titanium slag: | | | | | |
| Imports for consumption | 268,825 | 247,845 | 138,708 | 209,839 | 291,828 |
| Consumption | 252,826 | 225,541 | 166,401 | 200,858 | 252,027 |
| Rutile concentrate, natural and synthetic: | | | | | |
| Imports for consumption | 202,373 | 163,325 | 111,578 | 180,508 | 179,663 |
| Consumption | 285,371 | 238,937 | 265,558 | 317,902 | 305,278 |
| Sponge metal: | | | | | |
| Imports for consumption | 6,490 | 1,354 | 1,199 | [1]2,667 | [1]1,717 |
| Consumption[e] | 31,599 | 17,328 | 16,072 | 24,713 | 21,606 |
| Price, Dec. 31, per pound | $7.65 | $5.55 | $5.55 | $5.55 | $3.50-$4.00 |
| Titanium dioxide pigment: | | | | | |
| Production | 761,190 | 659,710 | 760,385 | [r]834,889 | 848,627 |
| Imports for consumption | 124,906 | 138,922 | 174,857 | 193,501 | 196,218 |
| Consumption, apparent[2] | 806,040 | 741,065 | 853,008 | [r]916,198 | 969,663 |
| Price, Dec. 31, cents per pound: | | | | | |
| Anatase | 69.0 | 69.0 | 69.0 | 69.0 | 72.0 |
| Rutile | 75.0 | 75.0 | 75.0 | 75.0 | 78.0 |
| **World**: Production: | | | | | |
| Ilmenite concentrate | [r]4,020,733 | [r]3,338,674 | [3]2,948,100 | [p] [3]3,401,503 | [e] [3]3,654,210 |
| Rutile concentrate, natural[3] | [r]398,673 | [r]373,449 | 342,081 | [p]387,872 | [e]401,900 |
| Titaniferous slag | 1,244,864 | 1,157,445 | 1,160,000 | [p]1,260,000 | [e]1,410,000 |

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data.

[1] Excludes sponge imported by the General Services Administration (GSA) for the national stockpile.

[2] Apparent consumption equals production plus imports minus exports minus stock increase.

[3] Excludes U.S. production data to avoid disclosing company proprietary data.

**Legislation and Government Programs.**—The Government's National Defense Stockpile goal for titanium sponge metal remained at 195,000 tons.[8] The Government stockpile inventory in December contained 25,965 tons of specification metal, including the 4,500 tons of sponge contracted for by the General Services Administration in 1983, of which 139 tons was added to inventory in 1984, and 4,361 tons in 1985. The stockpile also contained 10,866 tons of nonspecification material.

The Government stockpile goal for rutile was unchanged at 106,000 tons. The total rutile stockpile inventory at yearend was 39,186 tons.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict that would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, goals for titanium would be 3,900 tons in tier I and 21,100 tons in tier II. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

A final dumping margin of nearly 84% was found by the U.S. Department of Commerce on 150,000 pounds of sponge imported from the U.S.S.R. between August 1, 1982, and July 31, 1983. This decision means that the importers of that sponge will be assessed antidumping duties amounting to 83.96% of the price paid, and that future imports of sponge from the U.S.S.R. will be subject to a deposit equivalent to the antidumping margin, until publication of the findings for the next annual review period, August 1, 1983, to July 31, 1984. No U.S. imports for consumption of titanium sponge from the U.S.S.R. have been reported since the third quarter of 1983.

A U.S. Geological Survey press release on June 28, 1985, reported on potentially significant concentrations of ilmenite and zircon in offshore deposits 5 to 10 miles off the southeastern coast from Georgia to Virginia. Concentrations in some areas were at least 3% to 10% heavy minerals, compared with 3% to 5% heavy minerals in typical commercial onshore deposits. However, more work will be required to determine what commercial potential the deposits may have.

## DOMESTIC PRODUCTION

**Concentrates.**—U.S. producers of ilmenite were Associated Minerals (USA) Ltd. Inc. (AMU) at Green Cove Springs, FL, and E. I. du Pont de Nemours & Co. Inc. at Starke and Highland, FL.

As in 1984, AMU was the only producer of natural rutile concentrate. Kerr-McGee Chemical Corp. continued production of synthetic rutile at its 100,000-ton-per-year Mobile, AL, plant.

**Ferrotitanium.**—Ferrotitanium was produced by Ashland Chemical Co., Columbus, OH; Reactive Metals and Alloys Corp., West Pittsburg, PA; and Shieldalloy Corp., Newfield, NJ. Most of the production consisted of the 70% titanium grades.

**Metal.**—RMI Co., Niles, OH, the second largest U.S. titanium producer, built a $4 million welded-tube mill in an effort to expand the sales of its titanium mill products to the nonaerospace market. Tube sales for heat exchangers, water desalination equipment, and chemical processing systems were seen by RMI executives as the largest potential growth area for commercially pure titanium in the next decade. Initial capacity of about 1 million pounds per year of welded tubing was planned.

Wyman-Gordon Co., Worcester, MA, took over management of titanium sponge producer International Titanium Inc. (ITI), Moses Lake, WA, by increasing its holding in ITI to 80% from 41% at an additional cost of $8.4 million after investing $12.3 million in the company in 1984. Nearly all of the remaining shares in ITI are held by Mitsui & Co. Ltd. of Japan. Wyman-Gordon indicated it planned to become an integrated titanium producer and to expand later into titanium mill products, and earlier in the year had offered to purchase all of the shares of ITI held by Mitsui and Ishizuka Research Inc. of Japan; Titanium Industries Inc., Fairfield, NJ; and ITI founder Stephen

Yih.

Oregon Metallurgical Corp. was purchased by Owens-Corning Fiberglas Corp. as part of the sale of Armco Inc.'s aerospace and strategic materials group that included Ladish Co., a maker of forgings for aerospace and other industries, and HITCO Materials Div., a producer of high-performance composite materials for aerospace, defense, marine, and other applications. The sale was part of an Armco plan to sell up to $800 million of assets to reduce debt.

Titech International Inc., Pomona, CA, reportedly was investing $300,000 in a new vacuum annealing furnace and an expansion of its investment casting area, to be in operation by yearend. The company's total sales increased from $7 million to over $10 million in 1985, but growth in sales was expected to level off somewhat, with investment casting demand rising faster than that for rammed graphite castings.

A new company, the ALTA Group, Evans City, PA, was formed by three former employees of the TIMET Div. of Titanium Metals Corp. of America (TMCA), and began commercial production of high-purity titanium, primarily for use in the electronics industry. ALTA uses a molten-salt-bath electrolytic plating process, originally developed by the Bureau of Mines, in producing pure titanium in crystal, powder, or mill product form. The high-purity titanium product may be used in a variety of electronic, prosthetic, or corrosion-resistant applications, where standard titanium is not effective.[4]

Plans for a leveraged buyout of the TIMET Div. of TMCA by a TIMET management group were terminated. Allegheny International Inc. and NL Industries Inc., joint owners of TMCA, said that although the outlook for the titanium metal market is bright, they will continue to seek a buyer for TIMET in accordance with their strategy to divest themselves of companies outside their core businesses. TIMET executives and Kelso & Co., New York, which was arranging financing for the leveraged buyout in return for a share in the company, entered into an agreement to purchase TIMET at yearend 1984, but the management group reportedly was unable to arrange financing, partly because of lower-than-anticipated projected sales volume and profits for the division.

Cabot Corp. announced plans to sell most of its alloys and metal businesses because they were not meeting the company's financial performance objectives. The divestiture included its High Technology Materials Div., which produced titanium flat-rolled products and superalloys at its Kokomo, IN, plant and titanium tubing at its Arcadia, LA, plant. Cabot began producing flat-rolled titanium products at Kokomo in 1982, and had also planned to install titanium melting capacity at that location.

Colt Industries Inc. reportedly planned to sell its Crucible units, including Crucible Specialty Metals Div., which manufactured titanium rod, bar, and wire, as well as high-temperature alloys and other materials. The sale was to be a leveraged buyout by a management and employee group.

**Table 2.—Production and mine shipments of ilmenite concentrate[1] from domestic ores in the United States**

| Year | Production, gross weight (short tons) | Shipments | | |
|---|---|---|---|---|
| | | Gross weight (short tons) | $TiO_2$ content (short tons) | Value (thousands) |
| 1981 | 542,357 | 523,681 | 310,854 | $37,013 |
| 1982 | 263,391 | 233,063 | 145,725 | 19,093 |
| 1983 | W | W | W | W |
| 1984 | W | W | W | W |
| 1985 | W | W | W | W |

W Withheld to avoid disclosing company proprietary data.

[1] Includes a mixed product containing rutile, leucoxene, and altered ilmenite.

## Table 3.—U.S. titanium metal production capacity in 1985

| Company | Ownership | Plant location | Capacity (short tons) | |
|---|---|---|---|---|
| | | | Sponge | Ingot |
| Howmet Corp., Titanium Ingot Div. | Pechiney, France | Whitehall, MI | -- | 5,000 |
| International Light Metals Corp | Martin Marietta Corp., 60%; Nippon Kokan K.K., 40%. | Torrance, CA | -- | 6,000 |
| International Titanium Inc | Wyman-Gordon Co., 80%; Mitsui & Co. Ltd., Japan, nearly 20%. | Moses Lake, WA | 2,500 | -- |
| A. Johnson Metals Corp | Axel Johnson Group, Stockholm, Sweden. | Lionville, PA | -- | [1]1,500 |
| Lawrence Aviation Industries Inc. | Self | Port Jefferson, NY | -- | 1,500 |
| Oregon Metallurgical Corp | Owens-Corning Fiberglas Corp., 80%; public, 20% | Albany, OR | 4,500 | 8,000 |
| RMI Co | United States Steel Corp., 50%; National Distillers & Chemical Corp., 50%. | Ashtabula, OH<br>Niles, OH | 9,500<br>-- | --<br>18,000 |
| Teledyne Allvac | Teledyne Inc | Monroe, NC | -- | 4,000 |
| Teledyne Wah Chang Albany | do | Albany, OR | 1,500 | 1,000 |
| Titanium Metals Corp. of America. | NL Industries Inc., 50%; Allegheny International Inc., 50%. | Henderson, NV | 14,000 | 17,000 |
| Viking Metallurgical Corp | Quanex Corp | Verdi, NV | -- | [1]5,000 |
| Western Zirconium Inc | Westinghouse Electric Corp | Ogden, UT | 500 | 500 |
| Wyman-Gordon Co | Self | Worcester, MA | -- | 2,500 |
| Total | | | 32,500 | 70,000 |

[1] Single melt only; commercially pure ingot and slab.

**Pigment.**—Titanium dioxide pigment production increased for the third consecutive year, and in 1985 was about 93% of nominal capacity. Modifications of existing plants were in progress to increase capacity utilization and ease the tight supply situation that has resulted from record-high demand.

Kemira Oy of Finland purchased American Cyanamid Co.'s $TiO_2$ pigment plant at Savannah, GA, for about $100 million. The purchase brought Kemira's total capacity to nearly 200,000 tons per year, making Kemira the world's fifth largest $TiO_2$ producer.

## Table 4.—Components of U.S. titanium metal supply and demand

(Short tons)

| Component | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Production: | | | | | |
| Sponge | [1]26,400 | [1]15,600 | 13,966 | 24,326 | 23,257 |
| Ingot | 46,236 | 26,536 | 26,439 | 39,964 | 35,902 |
| Exports: | | | | | |
| Sponge | 58 | 36 | 39 | 171 | 51 |
| Other unwrought | 257 | 173 | 258 | 204 | 179 |
| Scrap | 3,280 | 4,287 | 5,379 | 4,109 | 6,760 |
| Ingot, slab, sheet bar, etc | 4,203 | 2,196 | 1,371 | 2,071 | 2,248 |
| Other wrought | 1,846 | 1,404 | 783 | 778 | 1,146 |
| Total | 9,644 | 8,096 | 7,830 | 7,333 | 10,384 |
| Imports: | | | | | |
| Sponge | 6,490 | 1,354 | 1,199 | [2]2,667 | [2]1,717 |
| Scrap | 3,787 | 1,277 | 1,572 | 1,850 | 2,134 |
| Ingot and billet | 244 | 212 | 81 | 176 | 179 |
| Mill products | 1,116 | 870 | 935 | 840 | 1,449 |
| Total[3] | 11,637 | 3,713 | 3,788 | 5,533 | 5,478 |
| Stocks, yearend: | | | | | |
| Government: Sponge (total inventory) | 32,331 | 32,331 | 32,331 | 32,470 | 36,831 |
| Industry: | | | | | |
| Sponge[4] | 3,720 | 3,350 | 3,136 | 3,147 | 4,755 |
| Scrap[4] | 10,484 | 11,073 | 12,635 | 12,489 | 11,686 |
| Ingot | 3,592 | 2,534 | 3,273 | 4,526 | 4,000 |
| Other | 7 | 3 | 22 | 18 | 34 |
| Total industry | 17,803 | 16,960 | 19,066 | 20,180 | 20,475 |

See footnotes at end of table.

### Table 4.—Components of U.S. titanium metal supply and demand —Continued

(Short tons)

| Component | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Reported consumption: | | | | | |
| Sponge[e] | 31,599 | 17,328 | 16,072 | 24,718 | 21,606 |
| Scrap[e] | 14,795 | 8,528 | 10,467 | 15,549 | 14,720 |
| Ingot | [r]43,795 | 27,580 | 26,232 | 39,062 | 37,174 |
| Mill products (net shipments)[4] | 25,492 | 18,281 | 15,949 | 22,808 | 23,253 |
| Castings (shipments)[4] | 209 | 260 | 240 | 268 | 411 |

[e]Estimated. [r]Revised.

[1]Calculated sponge metal production equals sponge consumption minus sponge imports plus sponge exports and adjustments for Government and industry stock changes.

[2]Excludes sponge imported by the General Services Administration (GSA) for the national stockpile.

[3]Data may not add to totals shown because of independent rounding.

[4]Bureau of the Census, Current Industrial Reports, Ser. DIB-991 and ITA-991.

### Table 5.—Capacities of U.S. titanium dioxide pigment plants on December 31, 1985

| Company and plant location | Pigment capacity (short tons per year) | |
|---|---|---|
| | Sulfate process | Chloride process |
| E. I. du Pont de Nemours & Co. Inc.: | | |
| Antioch, CA | -- | 35,000 |
| De Lisle, MS | -- | 150,000 |
| Edge Moor, DE | -- | 110,000 |
| New Johnsonville, TN | -- | 228,000 |
| Kemira Inc., Savannah, GA | 64,000 | 46,000 |
| Kerr-McGee Chemical Corp., Hamilton, MS | -- | 63,000 |
| SCM Corp., Glidden Pigments Group: | | |
| Ashtabula, OH | -- | 98,000 |
| Baltimore, MD | 66,000 | 50,000 |
| Total | 130,000 | 780,000 |

### Table 6.—Components of U.S. titanium dioxide pigment supply and demand

(Short tons unless otherwise specified)

| Component | 1981 (gross weight) | 1982 (gross weight) | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|---|---|
| | | | Gross weight | $TiO_2$ content | Gross weight | $TiO_2$ content | Gross weight | $TiO_2$ content |
| Production | 761,190 | 659,710 | 760,385 | 707,158 | [r]834,889 | [r]777,031 | 848,627 | 788,961 |
| Shipments:[1] | | | | | | | | |
| Quantity | 778,116 | 707,075 | 813,958 | 762,818 | 905,383 | 844,901 | 950,637 | 884,758 |
| Value thousands | $947,881 | $927,517 | $950,515 | $950,515 | $1,106,898 | $1,106,898 | $1,275,131 | $1,275,131 |
| Exports | 61,104 | 72,823 | 91,702 | 83,372 | 106,124 | 96,740 | 101,954 | 92,434 |
| Imports for consumption | 124,906 | 138,922 | 174,857 | [e]162,600 | 193,501 | [e]180,091 | 196,213 | 182,417 |
| Stocks, yearend | 102,189 | 86,933 | 77,465 | [e]72,035 | 83,533 | [e]77,744 | 56,756 | 53,765 |
| Consumption, apparent[2] | 806,040 | 741,065 | 853,008 | [e]791,816 | [r]916,198 | [e]854,673 | 969,663 | 902,923 |

[e]Estimated. [r]Revised.

[1]Includes interplant transfers.

[2]Apparent consumption equals production plus imports minus exports minus stock increase.

Sources: Bureau of the Census and Bureau of Mines.

## CONSUMPTION AND USES

**Concentrates.**—The total domestic consumption of titanium in concentrates increased about 2%. Slight decreases in consumption of ilmenite and rutile were more than offset by a 25% increase in titanium slag consumption.

**Metal.**—Demand for titanium was relatively soft for both aerospace and other industrial applications, and consumption of sponge and ingot decreased, although net mill product shipments were up slightly. Mill product shipments were 55% in the form of billet; 30% sheet, strip, plate, tubing, pipe, extrusions, and other; and 15% rod and bar.

Bar and billet were the major forms used for aircraft engines and airframes, while the other forms were used mainly for nonaerospace industrial applications. Mill product usage was estimated to be 75% for aerospace and 25% for other industrial applications.

Current use of titanium in large commercial aircraft represents about 6% of empty aircraft weight. Titanium is utilized where high-strength toughness, heat resistance, and high structural efficiency are required. Typical military aircraft uses are for A-10 ballistic armament; structural forgings and wing skins for F-14 and F-15 aircraft; rotor parts for helicopter blade systems; B-1B fracture-critical forgings and wing support sections; and rotor discs, blades, and compressor blades on various engines. Major nonaerospace industrial uses are those requiring superior resistance to corrosion, such as surface condensers in powerplants, heat exchangers, and chemical industry equipment.

The Titanium Development Association (TDA) continued its efforts on the dissemination of information about titanium applications and potential new markets for titanium. One example of such activities was the production of a 4-foot-high model of an offshore oil rig highlighting current and potential areas of titanium use, including compressor coolers, desalination units, and seawater intake piping and valves. The model was displayed at the Offshore Technology Conference in Houston, TX, in May 1985.

**Pigment.**—Consumption of $TiO_2$ pigments rose to a new peak for the third consecutive year, because of continued economic expansion and increased demand from the homebuilding industry. The proportion of shipments used for paper and plastics increased, with corresponding decreases in the remaining categories.

**Ferrotitanium.**—Consumption of ferrotitanium and titanium scrap in steel and other alloys decreased, mainly because of lower steel production.

**Table 7.—U.S. consumption of titanium concentrates**

(Short tons)

| Year | Ilmenite[1] |  | Titanium slag |  | Rutile (natural and synthetic)[2] |  |
|---|---|---|---|---|---|---|
|  | Gross weight | $TiO_2$ content[e] | Gross weight | $TiO_2$ content[e] | Gross weight | $TiO_2$ content[e] |
| 1981 | 856,116 | 511,022 | 252,826 | 186,020 | 285,371 | 266,596 |
| 1982 | 583,250 | 352,393 | 225,541 | 168,433 | 238,937 | 225,113 |
| 1983 | 730,578 | 474,285 | 166,401 | 127,267 | 265,558 | 250,418 |
| 1984: |  |  |  |  |  |  |
| Alloys and carbide | (3) | (3) | (4) | (4) | -- | -- |
| Pigments | 775,477 | 492,658 | 200,858 | 152,534 | 245,927 | 231,808 |
| Welding-rod coatings and fluxes | (3) | (3) | -- | -- | 4,165 | 3,911 |
| Miscellaneous[5] | 7,914 | 6,319 | -- | -- | 67,810 | 62,920 |
| Total | 783,391 | 498,977 | 200,858 | 152,534 | 317,902 | 298,639 |
| 1985: |  |  |  |  |  |  |
| Alloys and carbide | (3) | (3) | (4) | (4) | -- | -- |
| Pigments | 747,897 | 474,561 | 252,027 | 199,610 | 254,837 | 239,893 |
| Welding-rod coatings and fluxes | (3) | (3) | -- | -- | 5,192 | 4,881 |
| Miscellaneous[5] | 8,174 | 6,450 | -- | -- | 45,249 | 41,714 |
| Total | 756,071 | 481,011 | 252,027 | 199,610 | 305,278 | 286,488 |

[e] Estimated.

[1] Includes a mixed product containing rutile, leucoxene, and altered ilmenite.

[2] Includes synthetic rutile made in the United States.

[3] Included with "Miscellaneous" to avoid disclosing company proprietary data.

[4] Included with "Pigments" to avoid disclosing company proprietary data.

[5] Includes ceramics, chemicals, glass fibers, and titanium metal.

### Table 8.—U.S. distribution of titanium pigment shipments, titanium dioxide content, by industry

(Percent)

| Industry | 1981[r] | 1982[r] | 1983[r] | 1984[r] | 1985 |
|---|---|---|---|---|---|
| Paint, varnish, lacquer | 47.0 | 48.1 | 48.9 | 54.8 | 54.3 |
| Paper | 25.9 | 27.4 | 27.3 | 19.9 | 20.5 |
| Plastics (except floor covering and vinyl-coated fabrics and textiles) | 12.4 | 12.7 | 13.2 | 15.4 | 16.2 |
| Rubber | 2.4 | 2.6 | 1.8 | 2.0 | 1.7 |
| Printing ink | 1.4 | 1.0 | 1.1 | 1.2 | 1.0 |
| Ceramics | 1.5 | 1.2 | 1.0 | 1.0 | .7 |
| Other | 9.4 | 7.0 | 6.7 | 5.7 | 5.6 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

[r] Revised.

### Table 9.—U.S. consumption of titanium products[1] in steel and other alloys

(Short tons)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Carbon steel | 641 | 420 | 744 | 659 | 483 |
| Stainless and heat-resisting steel | 1,552 | 1,289 | 1,748 | 1,851 | 2,104 |
| Other alloy steel (includes HSLA) | 903 | 664 | 749 | 677 | 491 |
| Tool steel | W | W | W | W | W |
| Total steel[2] | 3,096 | 2,373 | 3,241 | 3,187 | 3,078 |
| Cast irons | 63 | 47 | 38 | 62 | 23 |
| Superalloys | 645 | 409 | 535 | 622 | 657 |
| Alloys, other than above | 254 | 200 | 252 | 473 | 357 |
| Miscellaneous and unspecified | 26 | 10 | 12 | 18 | 18 |
| Total consumption | 4,084 | 3,039 | 4,078 | 4,362 | 4,133 |

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1] Includes ferrotitanium containing 20% to 70% titanium and titanium metal scrap.
[2] Excludes data withheld and unspecified; included under "Miscellaneous and unspecified."

## STOCKS

The total $TiO_2$ content of industry stocks of concentrates increased 23% from the yearend 1984 level. The largest increase was in stocks of titanium slag, which rose about 31,000 tons, or 60%. The overall increase in concentrate stocks in 1985 followed rather substantial usage from stocks in 1983 and 1984.

### Table 10.—U.S. stocks of titanium concentrates and pigment, December 31

(Short tons)

| | Gross weight | $TiO_2$ content[e] |
|---|---|---|
| Ilmenite:[1] | | |
| 1983 | 398,884 | 254,237 |
| 1984[r] | 201,091 | 128,507 |
| 1985 | 237,430 | 147,357 |
| Titanium slag:[1] | | |
| 1983 | 78,378 | 61,026 |
| 1984[r] | 66,599 | 52,397 |
| 1985 | 105,919 | 83,711 |
| Rutile:[1] | | |
| 1983 | 130,035 | 122,189 |
| 1984[r] | 102,128 | 96,186 |
| 1985 | 115,973 | 109,319 |
| Titanium pigment:[2] | | |
| 1983 | 77,465 | 72,000 |
| 1984 | 83,533 | 77,700 |
| 1985 | 56,756 | 52,800 |

[e] Estimated. [r] Revised.
[1] Producer, consumer, and dealer stocks.
[2] Bureau of the Census. Producer stocks only.

## PRICES

**Concentrates.**—Published prices of titanium concentrates were generally higher by the end of 1985. However, published list prices of domestic ilmenite and rutile, in other than bulk lots, were suspended the entire year.

**Metal.**—Reported sales prices on sponge were lower by yearend. Prices on Japanese sponge under contract and spot prices were not published during 1985.

**Pigment.**—List prices for titanium dioxide pigment remained unchanged until the fourth quarter of 1985 when they increased 3 cents per pound and closed the year at the higher rate. Because of the high demand, there was very little discounting of list prices.

**Table 11.—Published prices of titanium concentrates and products**

| | | 1984[1] | 1985 |
|---|---|---|---|
| Concentrates: | | | |
| Ilmenite, f.o.b. eastern U.S. ports | per metric ton | $70.00-$75.00 | (2) |
| Ilmenite, f.o.b. Australian ports | do | 36.00- 38.00 | $38.00-$42.00 |
| Ilmenite, large lots, bulk, f.o.b. U.S. east coast | do | 44.00- 45.00 | 50.00- 56.00 |
| Rutile, f.o.b. eastern U.S. ports | per short ton | 460.00-490.00 | (2) |
| Rutile, bagged, f.o.b. Australian ports | do | 339.00-359.00 | 371.00-386.00 |
| Rutile, bulk, f.o.b. Australian ports | do | 319.00-335.00 | 315.00-328.00 |
| Rutile, large lots, bulk, f.o.b. U.S. east coast | do | 320.00-340.00 | 350.00-360.00 |
| Synthetic rutile, f.o.b. Mobile, AL | do | 350.00 | 350.00 |
| Titanium slag, 80% $TiO_2$, f.o.b. Sorel, Quebec[e] | per metric ton | 185.00 | 196.00 |
| Titanium slag, 85% $TiO_2$, f.o.b. Richards Bay, Republic of South Africa[e] | do | 200.00 | 212.00 |
| Metal: | | | |
| Sponge, reported sales | per pound | 4.00- 4.25 | 3.50- 4.00 |
| Sponge, Japanese, under contract, c.i.f. U.S. ports, including import duty | do | No quotation | No quotation |
| Mill products: | | | |
| Bar | do | [r]9.77 | 9.77 |
| Billet | do | [r]8.35 | 8.35 |
| Plate | do | [r]10.64 | 10.64 |
| Sheet | do | [r]12.73 | 12.73 |
| Strip | do | [r]13.45 | 13.45 |
| Pigment: | | | |
| Titanium dioxide pigment, f.o.b. U.S. plants, anatase | do | .69 | .72- .73 |
| Titanium dioxide pigment, f.o.b. U.S. plants, rutile | do | .75 | .78 |

[e] Estimated. [r] Revised.

[1] Yearend.

[2] List price suspended effective Jan. 1, 1985.

Sources: American Metal Market, Industrial Minerals (London), Metals Week, and industry contacts.

## FOREIGN TRADE

Exports of $TiO_2$ pigments decreased for the first time since 1980, while imports of pigment continued the upward trend that began in 1981.

Substantial increases in exports of most titanium metal categories occurred during 1985. Exports of sponge metal decreased 70%, and imports of sponge dropped 36%.

Imports of ilmenite, slag, and synthetic rutile increased 24% to 50%, much more than offsetting the 7% decrease in imports of natural rutile.

## Table 12.—U.S. exports of titanium products, by class

| Class | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| **Concentrates:** |  |  |  |  |  |  |
| Ilmenite | 865 | $26 | 3,807 | $151 | -- | -- |
| Rutile | 3,526 | 980 | 4,844 | 1,784 | 27,759 | $6,953 |
| Total | 4,391 | 1,006 | 8,651 | [1]1,936 | 27,759 | 6,953 |
| **Metal:** |  |  |  |  |  |  |
| Sponge | 39 | 203 | 171 | 967 | 51 | 338 |
| Other unwrought | 258 | 1,896 | 204 | 1,224 | 181 | 2,604 |
| Scrap | 5,379 | 7,074 | 4,109 | 7,168 | 6,760 | 14,533 |
| Ingots, billets, slabs, etc | 1,371 | 29,232 | 2,071 | 40,993 | 2,248 | 40,942 |
| Other wrought | 783 | 22,965 | 778 | 20,509 | 1,147 | 29,481 |
| Total | 7,830 | 61,370 | 7,333 | 70,861 | [1]10,388 | 87,898 |
| **Pigment and oxides:** |  |  |  |  |  |  |
| Titanium dioxide pigments | 91,702 | 86,900 | 106,124 | 97,804 | 101,954 | 108,384 |
| Titanium compounds, except pigment-grade | 1,819 | 5,232 | 2,123 | 5,024 | 1,247 | 4,486 |
| Total | 93,521 | 92,132 | 108,247 | 102,828 | 103,201 | 112,870 |

[1] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

## Table 13.—U.S. imports for consumption of titanium concentrates, by country

| Concentrate and country | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| **Ilmenite:** |  |  |  |  |  |  |
| Australia | 259,328 | $9,262 | 409,605 | $11,063 | 506,539 | $14,060 |
| Indonesia | -- | -- | -- | -- | 265 | 530 |
| Total | 259,328 | 9,262 | 409,605 | 11,063 | 506,804 | 14,590 |
| **Titanium slag:** |  |  |  |  |  |  |
| Canada | 127,691 | 18,533 | 160,155 | 25,081 | 195,230 | 36,350 |
| South Africa, Republic of | 11,016 | 1,628 | 49,685 | 7,702 | 96,598 | 15,881 |
| Total[1] | 138,708 | 20,161 | 209,839 | 32,783 | 291,828 | 52,231 |
| **Rutile, natural:** |  |  |  |  |  |  |
| Australia | 80,096 | 16,450 | 93,871 | 25,046 | 66,055 | 19,062 |
| Canada | -- | -- | 219 | 55 | 258 | 43 |
| Sierra Leone | -- | -- | 48,436 | 13,326 | 32,994 | 10,822 |
| South Africa, Republic of | 10,817 | 3,365 | 15,939 | 2,674 | 44,146 | 10,094 |
| Other | 79 | 21 | -- | -- | 3,150 | 488 |
| Total[1] | 90,992 | 19,836 | 158,465 | 41,100 | 146,602 | 40,509 |
| **Rutile, synthetic:** |  |  |  |  |  |  |
| Australia | 11,118 | 1,767 | 22,043 | 3,810 | 33,061 | 3,458 |
| France | 127 | 111 | -- | -- | -- | -- |
| Japan | 617 | 235 | -- | -- | -- | -- |
| Taiwan | 8,723 | 1,583 | -- | -- | -- | -- |
| Total[1] | 20,586 | 3,696 | 22,043 | 3,810 | 33,061 | 3,458 |
| **Titaniferous iron ore:**[2] |  |  |  |  |  |  |
| Canada | 2,124 | 107 | 1,966 | 77 | 858 | 38 |

[1] Data may not add to totals shown because of independent rounding.

[2] Includes materials consumed for purposes other than production of titanium commodities, principally heavy aggregate and steel furnace flux.

Source: Bureau of the Census. Data adjusted by the Bureau of Mines.

## Table 14.—U.S. imports for consumption of titanium dioxide pigments, by country

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Australia | 5,591 | $5,824 | 5,277 | $5,398 | 5,285 | $5,967 |
| Belgium-Luxembourg | 14,456 | 11,287 | 10,840 | 9,824 | 16,459 | 15,508 |
| Canada | 25,563 | 27,396 | 26,212 | 29,388 | 26,658 | 30,019 |
| Finland | 4,829 | 4,678 | 6,079 | 5,954 | 5,799 | 6,200 |
| France | 31,195 | 30,032 | 47,801 | 45,107 | 39,379 | 42,167 |
| Germany, Federal Republic of | 36,659 | 35,804 | 34,980 | 34,156 | 39,723 | 38,955 |
| Italy | 1,223 | 1,082 | 1,078 | 1,032 | 1,520 | 1,855 |
| Japan | 4,888 | 4,870 | 4,546 | 4,900 | 5,378 | 6,267 |
| Mexico | 67 | 61 | 1,668 | 1,201 | 3,289 | 4,050 |
| Netherlands | 254 | 211 | 189 | 198 | 1,238 | 1,120 |
| Norway | 6,428 | 5,638 | 6,931 | 6,304 | 6,978 | 5,968 |
| South Africa, Republic of | -- | -- | -- | -- | 551 | 634 |
| Spain | 23,006 | 18,784 | 22,129 | 20,863 | 21,283 | 23,659 |
| United Kingdom | 19,761 | 19,135 | 22,847 | 20,857 | 21,242 | 22,880 |
| Yugoslavia | 155 | 115 | 2,597 | 1,447 | 516 | 508 |
| Other[1] | [r]781 | [r]577 | [r]329 | [r]322 | 913 | 1,054 |
| Total[2] | 174,857 | 165,495 | 193,501 | 186,952 | 196,213 | 206,809 |

[r] Revised.

[1] Includes Algeria, Austria, Brazil, China, Denmark, Dominican Republic, Hong Kong, India, Ireland, the Republic of Korea, Macao, Poland, Singapore, Sweden, Switzerland, and Taiwan, in one or more of these years.

[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## Table 15.—U.S. imports for consumption of titanium metal, by class and country

| Class and country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Unwrought: Sponge: | | | | | | |
| China | 1 | $4 | -- | -- | -- | -- |
| Japan | 976 | 6,761 | [1]2,662 | $15,789 | [1]1,689 | $10.007 |
| Korea, Republic of | -- | -- | -- | -- | 28 | 156 |
| U.S.S.R | 193 | 913 | -- | -- | -- | -- |
| United Kingdom | 30 | 177 | [1]5 | 26 | (2) | 1 |
| Total[3] | 1,199 | 7,856 | [1]2,667 | 15,815 | [1]1,717 | 10,164 |
| Ingot and billet: | | | | | | |
| Canada | 7 | 102 | 6 | 62 | 29 | 247 |
| China | -- | -- | (2) | 1 | -- | -- |
| France | -- | -- | 38 | 162 | (2) | 15 |
| Germany, Federal Republic of | 19 | 405 | 30 | 561 | 46 | 844 |
| Japan | 44 | 546 | 77 | 1,327 | 101 | 950 |
| U.S.S.R | 4 | 38 | -- | -- | -- | -- |
| United Kingdom | 6 | 133 | 26 | 328 | 2 | 49 |
| Other | (2) | 4 | (2) | 5 | (2) | 26 |
| Total[3] | 81 | 1,228 | 176 | 2,447 | 179 | 2,131 |
| Waste and scrap: | | | | | | |
| Austria | 39 | 55 | 217 | 390 | -- | -- |
| Belgium | 66 | 89 | 28 | 11 | 47 | 61 |
| Canada | 451 | 2,240 | 190 | 320 | 117 | 155 |
| China | 22 | 19 | 68 | 168 | 372 | 839 |
| France | 62 | 95 | 149 | 451 | 122 | 498 |
| Germany, Federal Republic of | 166 | 365 | 294 | 851 | 87 | 316 |
| Japan | 44 | 130 | 117 | 522 | 352 | 1.175 |
| Sweden | 90 | 168 | 100 | 301 | 90 | 311 |
| Switzerland | 117 | 184 | -- | -- | 162 | 318 |
| U.S.S.R | -- | -- | 90 | 270 | 78 | 194 |
| United Kingdom | 463 | 1,036 | 544 | 2,215 | 595 | 2,001 |
| Other | 52 | 80 | 53 | 202 | 111 | 207 |
| Total[3] | 1,572 | 4,461 | 1,850 | 5,703 | 2,134 | 6,075 |

See footnotes at end of table.

Table 15.—U.S. imports for consumption of titanium metal, by class and country —Continued

| Class and country | 1983 Quantity (short tons) | 1983 Value (thousands) | 1984 Quantity (short tons) | 1984 Value (thousands) | 1985 Quantity (short tons) | 1985 Value (thousands) |
|---|---|---|---|---|---|---|
| Wrought titanium: | | | | | | |
| Canada | 317 | $5,219 | 212 | $3,701 | 390 | $6,293 |
| Germany, Federal Republic of | ([2]) | 2 | 6 | 140 | ([2]) | 18 |
| Japan | 605 | 8,842 | 529 | 6,091 | 987 | 13,128 |
| United Kingdom | 8 | 258 | 68 | 1,130 | 55 | 1,254 |
| Other | 5 | 33 | 25 | 441 | 18 | 345 |
| Total[3] | 935 | 14,354 | 840 | 11,504 | 1,449 | 21,038 |

[1] Excludes sponge imported by GSA for the national stockpile.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

World production of titanium concentrates rose for the second consecutive year because of the continued increase in $TiO_2$ pigment production and demand. World prices of concentrates and pigment increased in response to the high demand. World demand for $TiO_2$ pigment in 1985 was about 2.6 million tons.

Titanium sponge metal production in the market economy countries rose to about 49,000 tons because of increased production in Japan, despite somewhat reduced output in the United States and the United Kingdom.

**Australia.**—Australia again was the largest producer of titanium minerals with exports of ilmenite, in order of decreasing volume, mainly to the United States, the United Kingdom, Spain, the U.S.S.R., Japan, Brazil, and France, and exports of rutile, in order of decreasing volume, mainly to the United States, the United Kingdom, and Japan.

Because of strong demand for ilmenite, rutile, monazite, and zircon, the Australian mineral sands industry planned to increase its production capacity of mineral sands and synthetic rutile. Mineral Deposits Ltd. planned to begin a new operation in August that would bring its production rate to 33,000 tons per year each of rutile and zircon by early 1986. In August-September 1985, $TiO_2$ Corp. was introduced as a major new mineral sands operator on Australia's west coast and by 1988, planned to exploit deposits acquired from Western Mining Corp. at Cooljarloo and Jurien Bay north of Perth. Westralian Sands Ltd. planned to build a 110,000-ton-per-year synthetic rutile plant at Capel, Western Australia, by mid-1987. Associated Minerals Consolidated Ltd. (AMC) was to add to its existing synthetic rutile capacity of 66,000 tons per year, at Capel, by building a 120,000-ton-per-year plant near Geraldton, Western Australia, also to be completed in 1987. Total Australian synthetic rutile capacity by 1987 was thus expected to increase from the current level of 66,000 tons per year to about 300,000 tons per year.

Du Pont reportedly agreed to sell its 50% share in Allied Eneabba Ltd., a producer of ilmenite and zircon in Western Australia, to Renison Goldfields Consolidated Ltd. Renison's subsidiary, AMC, is Australia's largest producer of ilmenite, with mining and processing operations in the Eneabba and Perth areas.

**Belgium.**—Inco Ltd. reportedly reached an agreement for Inco Alloy Products Ltd. (IAPL) to acquire a $2.5 million share in Titech Europe, a titanium castings company that was in receivership following the withdrawal of the parent company, Titech International Inc. A new company was to be formed, jointly owned by IAPL (60%) and the Walloon regional development authority, known as the Société Regionale d'Investissement de Wallonie (40%), according to reports. An extensive program of capital investment and research and development was planned to increase the product range of the new company, to be known as the Société de Technologie du Titane et des Alliages Speciau.

**Brazil.**—Du Pont was considering a joint venture with Cia. Vale do Rio Doce (CVRD), owned by the Government of Brazil, to construct a 66,000-ton-per-year $TiO_2$ pigment plant in Brazil. CVRD would supply Du Pont with 220,000 tons per year of anatase concentrates from a $100 million plant that CVRD was to begin building in 1985 in the State of Minas Gerais, and Du Pont would supply technology for producing $TiO_2$ pigment from the anatase concentrates. The $TiO_2$ plant would also cost about $100 million and begin preduction in 1989. CVRD reportedly began operation of a 15,000-ton-per-year pilot plant to produce anatase concentrates in 1983.[5]

International Minerals & Chemical Corp. (IMC), Northbrook, IL, reportedly signed a letter of intent with the Goiás State government indicating the company's interest in investing in a titanium concentrate plant that would be built in Catalao, Goiás, in the next 2 years. The proposed agreement tentatively called for IMC to invest up to $200 million in a plant with an estimated capacity of 330,000 tons per year of anatase concentrate containing up to 90% $TiO_2$. The project would be in a new market area for IMC, which is a major worldwide supplier of fertilizers, ferroalloys, and industrial minerals. Anatase ore reserves are controlled by a Brazilian State company, Metais de Goiás S.A., and would be leased to IMC for 25 years.[6]

**Canada.**—NL Industries planned to build a 40,000-ton-per-year chloride-process $TiO_2$ plant at Varennes, Quebec, to be completed by mid-1987 at a cost of $50 million. NL Industries' subsidiary, NL Chem Canada Ltd., operates a 40,000-ton-per-year sulfate-process $TiO_2$ plant at Varennes.

Chemetics International Co., North York, Ontario, announced a project for recovering spent acid from sulfate-process $TiO_2$ production. Chemetics, Tioxide Canada Inc. (Dorval, Quebec), NL Chem Canada, and QIT-Fer et Titane Inc. (Sorel, Quebec) agreed in principle to build a unit for processing 110 tons per day of waste acid at Tioxide Canada's Tracy, Quebec, $TiO_2$ plant. The process, reportedly patented by Chemetics, involves total evaporation of sulfuric acid in strong acid waste, followed by separation of the solid metal sulfates from the vapor phase, and production of 93% to 96% sulfuric acid by partial condensation.[7]

**China.**—China reportedly contracted to buy a vacuum arc melting furnace for the manufacture of titanium ingots. The furnace was to be installed in the Baoji metal plant in Shaanxi Province, to improve quality as well as increasing output to 1,300 tons per year.

**Finland.**—The Otanmaki underground mine, operated by Rautaruukki Oy, was closed in April 1985 because of high operating costs. Besides ilmenite, the mine produced magnetite, pyrite, and vanadium pentoxide.

**Germany, Federal Republic of.**—NL Industries began operation of its new 44,000-ton-per-year chloride-process $TiO_2$ plant at Leverkusen, which replaces some of its older sulfate-process capacity at that location. NL Industries' total annual $TiO_2$ production capacity in the Federal Republic of Germany was about 88,000 tons of chloride-process and 40,000 tons of sulfate-process capacity at Leverkusen, and 66,000 tons of sulfate-process capacity at Nordenham. The company planned to build acid recycling plants for both the Nordenham and Leverkusen facilities by 1989, the year permission was scheduled to end for dumping waste acid into the North Sea.

**India.**—Mining was scheduled to begin in 1985 at the Orissa Sands Complex. Indian Rare Earths Ltd. planned to mine 3.2 million tons of raw sand annually to provide 240,000 tons of ilmenite, 33,000 tons of sillimanite, 11,000 tons of rutile, 4,000 tons of monazite, and 2,000 tons of zircon.[8]

**Italy.**—Elettrochimica Marco Ginatta (EMG) reportedly was building a 1,300-ton-per-year electrolytic process titanium sponge, crystals, and powder plant in Trieste, in partnership with Instituto par la Reconstruzione Industriale, the state holding company that owns the major steel company, Finanziaria Siderurgica S.p.A. EMG hoped to have the plant in production by early 1987 and was also seeking partners for a 10,000-ton-per-year titanium sponge plant elsewhere in Europe.[9]

**Japan.**—Toho Titanium Co. Ltd. expanded its ingot capacity to about 9,000 tons per year from 3,300 tons per year, through the purchase of a new vacuum arc melting furnace from Consarc Corp., Rancocas, NJ. In December 1985, Toho was planning to start deliveries of titanium ingots weighing 16.5 tons.

Total annual Japanese sponge production capacity at yearend was about 34,800 tons, distributed among the four producers as follows: Osaka Titanium Co. Ltd., 17,000 tons; Toho, 13,200 tons; Nippon Soda Co. Ltd., 2,400 tons; and Showa Titanium Co. Ltd., 2,200 tons.

In November, Osaka and Nippon Soda reportedly reduced their production rates because of lower-than-expected demand from the aerospace industry and a drop in sales prices of about 20% caused by the increased strength of the Japanese yen relative to the U.S. dollar. However, Toho and Showa continued to operate at levels reached earlier in the year, so that overall utilization of Japan's sponge capacity in the fourth quarter was about 62%. Total 1985 titanium sponge production in Japan was 24,500 tons.

**Norway.**—The Central Bureau of Statistics estimated Norway's titanium reserves to be sufficient for 60 years of operation at the current production rate, indicating total reserves of 49 million tons of ilmenite concentrate containing about 22 million tons of $TiO_2$. The K/S Ilmenittsmelteverket A/S (KSI) plant, being built in Tyssedal to smelt 385,000 tons per year of ilmenite and recover 220,000 tons per year of 75% $TiO_2$ slag, was expected to start trial runs in September 1986 and be in full production in 1987. KSI is a limited partnership between state-owned DNN Industries A/S (83.3%), Kronos Titan A/S (7.5%), Titania A/S (7.5%), and shipowner Atle Jebsen (1.67%). Estimated total cost of the project was about $160 million.[10]

**Saudi Arabia.**—A private sector Saudi industrial group, IDI Ltd., was planning to build a 55,000-ton-per-year $TiO_2$ plant at Al-Jubail on the Persian Gulf. The plant probably would use chloride-process technology and would cost about $140 million. The plant would supply domestic and export markets.[11]

**South Africa, Republic of.**—Richards Bay Minerals planned to spend about $68 million over the next 2 years to expand its heavy minerals mining and smelting operations in the Republic of South Africa. The smelter capacity reportedly will be increased 50% to about 720,000 tons per year of 85% $TiO_2$ slag by building a third furnace.

**Taiwan.**—Du Pont obtained permission from the Government of Taiwan to build a 66,000-ton-per-year $TiO_2$ pigment plant. Estimated cost of the plant was about $150 million, with a 1988 startup date. Du Pont estimated that worldwide $TiO_2$ demand was growing at 1.5% per year, but that demand in the Asian-Pacific and Latin American regions was growing at double that rate.

**U.S.S.R.**—Production of titanium sponge metal was estimated to be 47,000 tons. Annual production capacity was estimated to be about 53,000 tons. Imports of ilmenite from Australia declined 40% to 69,000 tons.

**United Kingdom.**—In September, Billiton (UK) Ltd. sold its 62.5% share of Deeside Titanium Ltd. to Rolls Royce Ltd., bringing Rolls Royce's share in Deeside to 82.5%. IMI Titanium Ltd. owns the remaining 17.5%. Deeside was reportedly operating its 5,500-ton-per-year sponge plant at a 1,500-ton-per-year rate, the estimated level required to supply the needs of Rolls Royce.

**Table 16.—Titanium: World production of concentrates (ilmenite, leucoxene, rutile, and titaniferous slag), by country**[1]

(Short tons)

| Concentrate type and country | 1981 | 1982 | 1983 | 1984$^{p}$ | 1985$^{e}$ |
|---|---|---|---|---|---|
| Ilmenite and leucoxene:[2] | | | | | |
| Australia: | | | | | |
| Ilmenite | 1,456,303 | 1,266,788 | 987,900 | 1,260,224 | 1,380,000 |
| Leucoxene | 21,232 | 21,758 | 14,725 | 17,509 | 19,000 |
| Brazil | $^{r}$17,478 | $^{r}$12,480 | 33,568 | 45,134 | 50,000 |
| China$^{e}$ | 150,000 | 150,000 | 154,000 | 154,000 | 154,000 |
| Finland | 178,023 | 184,968 | 180,669 | $^{e}$184,000 | 150,000 |
| India[3] | 179,141 | $^{r}$168,585 | 148,234 | 154,323 | 187,000 |
| Malaysia[4] | 190,432 | 111,556 | 245,509 | 259,025 | 303,000 |
| Norway | $^{r}$727,088 | 608,215 | 612,826 | 729,027 | 810,500 |
| Portugal | $^{r}$441 | $^{r}$645 | 298 | 181 | 160 |
| Sri Lanka | 88,197 | 75,268 | 90,145 | 112,489 | 110,000 |
| Thailand | 41 | 20 | 226 | 591 | 550 |
| U.S.S.R.$^{e}$ | 470,000 | 475,000 | 480,000 | 485,000 | 490,000 |
| United States[5] | 542,357 | 263,391 | W | W | W |
| Total | $^{r}$4,020,733 | $^{r}$3,338,674 | 2,948,100 | 3,401,503 | 3,654,210 |
| Rutile: | | | | | |
| Australia | 254,432 | 243,277 | 174,404 | 200,048 | 225,000 |
| Brazil | $^{r}$190 | $^{r}$258 | 510 | 454 | 500 |
| India[3] | 7,397 | $^{r}$6,374 | $^{r}$ $^{e}$6,100 | $^{r}$ $^{e}$6,600 | 7,700 |
| Sierra Leone[6] | 55,992 | 52,590 | 79,146 | 100,641 | 89,000 |
| South Africa, Republic of$^{e}$ | 55,000 | 52,000 | 62,000 | 62,000 | 61,000 |
| Sri Lanka | 14,662 | 7,950 | 8,921 | 7,129 | 7,700 |

See footnotes at end of table.

Table 16.—Titanium: World production of concentrates (ilmenite, leucoxene, rutile, and titaniferous slag), by country[1] —Continued

(Short tons)

| Concentrate type and country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Rutile —Continued | | | | | |
| U.S.S.R.[e] | 11,000 | 11,000 | 11,000 | 11,000 | 11,000 |
| United States | W | W | W | W | W |
| Total | [r]398,673 | [r]373,449 | 342,081 | 387,872 | 401,900 |
| Titaniferous slag: | | | | | |
| Canada[7] | 836,864 | 737,445 | 700,000 | 800,000 | 930,000 |
| South Africa, Republic of[e] [8] | 408,000 | 420,000 | 460,000 | 460,000 | 480,000 |
| Total | 1,244,864 | 1,157,445 | 1,160,000 | 1,260,000 | 1,410,000 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1] Table excludes production of unbeneficiated anatase ore in Brazil, in short tons, as follows: 1981—3,208,185; 1982—3,136,054; 1983—2,610,028; 1984—2,943,538; and 1985—3,000,000 (estimated). This material reportedly contains 20% $TiO_2$. Table includes data available through June 24, 1986.

[2] Ilmenite is also produced in Canada and in the Republic of South Africa, but this output is not included here because an estimated 90% of it is duplicative of output reported under "Titaniferous slag," and the rest is used for purposes other than production of titanium commodities, principally as steel furnace flux and heavy aggregate.

[3] Data are for fiscal year beginning Apr. 1 of year stated.

[4] Exports.

[5] Includes a mixed product containing ilmenite, leucoxene, and rutile.

[6] Contains 96% $TiO_2$.

[7] Contained 72% $TiO_2$ in 1981-82, 74% $TiO_2$ in 1983, and 80% $TiO_2$ in 1984-85.

[8] Contains 85% $TiO_2$.

## TECHNOLOGY

The Bureau of Mines issued a report on contract research in which engineering profiles and cost data were obtained on foreign titanium mineral properties. Capital and operating costs were estimated for all reported currently operating and potential future projects in market economy countries.[12] The Bureau also investigated the recovery of titanium from perovskite ($CaTiO_3$) concentrates by using sulfuric acid-$CaTiO_3$ reactions at atmospheric pressure. Under some conditions, over 98% of the titanium was rapidly converted to water-soluble sulfates.[13] A U.S. patent was developed based on this work.[14] In other Bureau research, titanium diboride ($TiB_2$) was used as a 0% to 12% stoichiometric constituent of an iron-base alloy system being investigated as a potential replacement for cobalt-base alloys for some uses. A range of $TiB_2$ contents resulting in most promising properties was determined for further research.[15]

New evidence was published indicating that the Trail Ridge mineral sands deposit in Florida formed mainly as a great sand dune or dune complex, rather than as a beach deposit, as previously thought. The new evidence, consisting of high-angle crossbeds diagnostic of an aeolian dune environment, was revealed in 1968 and again in 1985 when the dredge pond at Du Pont's mining operation was lowered to reach some deep ore. The high water table had previously prevented direct examination of the ore structure. Since exploration for heavy minerals in the Southeastern United States has been aimed almost entirely at ancient shoreline placers, some dune deposits may have been overlooked.[16]

The role of titanium minerals and pigments in welding fluxes was discussed in an article examining the industrial minerals used for coated electrodes, flux-cored wires, and granular fluxes. A description of relevant welding processes was included.[17]

U.S. Navy officials reported that the *Sea Cliff*, one of the Navy's three Turtle class deep-diving submarines, had made an ocean dive of 20,000 feet off the coast of Central America. The 31-foot *Sea Cliff* had been refitted with a special titanium hull and silver-zinc batteries, allowing independent operation at 20,000 feet for more than 16 hours. The original design of the Turtle class submarines specified a standard operating depth of 6,500 feet.[18]

Recognizing the need for a single, comprehensive, concise, up-to-date source book on titanium, TDA published in book form a compilation of articles on various aspects of titanium technology. Most of these articles have already appeared in print, mainly in the "Journal of Metals." However, a major new chapter was included on the history of titanium, written especially for this book.[18]

In response to a need for improved performance of gas turbine aircraft engines, the U.S. Air Force worked on projects that could result in radically new materials for engine components. An important part of the Air Force Wright Aeronautical Materials Laboratory program at Wright-Patterson Air Force Base, Dayton, OH, is to develop low-density, high-strength, and high-temperature titanium alloys, using rapid solidification technology. Significant quantities of rapidly solidified titanium may be produced by a melt spinning technique by the end of 1986. Low density may be achieved by alloying with lithium, beryllium, or silicon, and the Air Force applied for a patent on such a process. An Air Force objective is to use new high-temperature alloys in a new fighter aircraft engine in 1992.[20] Development of such improved alloys is expected to increase titanium demand in the 1990's.

The properties and advantages of patented Lockheed Missiles and Space Co. titanium alloys Transage 175, (2.7Al-13V-7Zn-2Zr) and Transage 134 (2.5Al-12V-2Sn-6Zr) were described. In aerospace applications tests, Transage 175, a high-temperature alloy, was used to produce jet engine components that were found to be structurally superior to components made with the standard Ti-6Al-4V alloy and were lower cost. Transage 134 is a high-strength alloy that can be press forged at temperatures as low as 1,200° F, compared with 1,650° F to 1,800° F for the Ti-6Al-4V alloy.[21]

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[1] Physical scientist, Division of Nonferrous Metals.

[2] Mineral data assistant, Division of Nonferrous Metals.

[3] Weight units used in this chapter are short tons unless otherwise specified.

[4] Rogers, J. ALTA's Pure Titanium Used on Electronic Chips. Am. Met. Mark., v. 93, No. 141, July 24, 1985, p. 6.

[5] Turner, R., J. Ryser, and A. Agoos. Du Pont Seeks a New $TiO_2$ Source in Anatase. Chem. Week, v. 137, No. 1, July 3, 1985, pp. 7, 10.

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[17] Griffiths, J. Minerals in Welding Fluxes—The Whys and Wherefores. Ind. Miner. (London), No. 210, Mar. 1985, pp. 19-39.

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[19] Froes, F. H., D. Eylon, and H. B. Bomberger (ed). Titanium Technology: Present Status and Future Trends. Titanium Devel. Assoc., Dayton, OH, 1985, 191 pp.

[20] Weiss, B. R/S Titanium Quantities Expected by End of 1986. Am. Met. Mark., v. 93, No. 223, Nov. 18, 1985, pp. 21, 32.

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# Tungsten

## By Philip T. Stafford[1]

Consumption of tungsten concentrate decreased 20% and imports fell 18% from those of 1984. Mine shipments decreased 16% from those of 1984, remaining lower than those of any year since 1934. Prices of concentrate from domestic mines remained at a relatively low level, decreasing 19% from those of 1984.

More than 95% of domestic production came from three mining operations in California and Colorado. Most mines, mills, and ammonium paratungstate (APT) plants were closed all or part of the year.

**Domestic Data Coverage.**—Domestic production data for tungsten are developed by the Bureau of Mines by means of three separate, voluntary surveys. These surveys are "Tungsten Ore and Concentrate," "Tungsten Concentrate and Tungsten Products," and "Tungsten Concentrate." Of the 43 operations to which surveys were sent, all responded, representing 100% of the total production shown in table 1.

### Table 1.—Salient tungsten statistics

(Metric tons of tungsten content unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Concentrate: | | | | | |
| Mine production | 3,605 | 1,521 | 980 | 1,203 | 996 |
| Mine shipments | 3,545 | 1,575 | 1,016 | 1,173 | 983 |
| Value thousands | $62,231 | $22,062 | $10,528 | $18,409 | $9,143 |
| Consumption | 9,839 | 4,506 | 5,181 | 8,577 | 6,838 |
| Shipments from Government stocks | 958 | 344 | 259 | 1,368 | 902 |
| Exports | 79 | 305 | 1 | 129 | 124 |
| Imports for consumption | 5,831 | 3,528 | 2,861 | 5,807 | 4,746 |
| Stocks, Dec. 31: | | | | | |
| Producer | 108 | 54 | 47 | 46 | 60 |
| Consumer | 671 | 1,765 | 1,085 | 959 | 1,077 |
| Ammonium paratungstate: | | | | | |
| Production | 8,855 | 4,914 | 5,021 | 7,839 | 6,527 |
| Consumption | 9,165 | 5,873 | 5,655 | 8,808 | 7,941 |
| Stocks, Dec. 31: Producer and consumer | 699 | 748 | 970 | 1,191 | 1,056 |
| Primary products: | | | | | |
| Production | 9,960 | 6,441 | 6,020 | 9,799 | 8,219 |
| Consumption | 9,613 | 6,349 | 6,523 | 10,216 | 8,096 |
| Stocks, Dec. 31: | | | | | |
| Producer | 1,472 | 1,477 | 1,433 | 1,850 | 1,968 |
| Consumer | 936 | 933 | 1,446 | 1,585 | 1,206 |
| World: Concentrate: | | | | | |
| Production | [r]50,269 | [r]46,921 | 40,821 | [p]46,478 | [e]46,989 |
| Consumption | [r]47,986 | [r]42,170 | 42,705 | [p]50,072 | [e]47,298 |

[e]Estimated. [p]Preliminary. [r]Revised.

**Legislation and Government Programs.**—The General Services Administration (GSA) Office of Stockpile Transactions continued to sell excess stockpiled tungsten concentrate on the basis of monthly sealed bids. Regular offerings of excess concentrate were made at the disposal rate of 136,078 kilograms of tungsten content per month, of which 102,058 kilograms was for domestic use and 34,020 kilograms was for export. Additionally, supplemental offerings were made at the rate of 90,719 kilograms per month, of which 68,039 kilograms was for domestic use and 22,680 kilograms was for export. As a result of the regular and supplemental offerings, concentrate sales totaled 694,370 kilograms of tungsten, of which 611,587 kilograms was for domestic use and 82,783 kilograms was for export.

Actual shipment of excess concentrate from the stockpile totaled 902,401 kilograms of tungsten content in concentrate.

All stockpile sales of tungsten concentrate were discontinued as of October 1 until further notice because the transaction fund had reached its legal limit ceiling of $250 million. Hence, no sales were made after September.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, tungsten would be categorized in tier II, and the goal would be 23,682 metric tons of tungsten metal equivalent. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

**Table 2.—U.S. Government tungsten stockpile material inventories and goals**

(Metric tons of tungsten content)

| Material | Goals | Inventory by program, Dec. 31, 1985 | | |
|---|---|---|---|---|
| | | National stockpile | DPA[1] inventory | Total |
| Tungsten concentrate: | | | | |
| Stockpile grade | 25,152 | 24,670 | 72 | 24,742 |
| Nonstockpile grade | -- | 11,846 | 46 | 11,892 |
| Total | 25,152 | 36,516 | 118 | 36,634 |
| Ferrotungsten: | | | | |
| Stockpile grade | -- | 381 | -- | 381 |
| Nonstockpile grade | -- | 537 | -- | 537 |
| Total[2] | -- | 919 | -- | 919 |
| Tungsten metal powder: | | | | |
| Stockpile grade | 726 | 711 | -- | 711 |
| Nonstockpile grade | -- | 150 | -- | 150 |
| Total | 726 | 861 | -- | 861 |
| Tungsten carbide powder: | | | | |
| Stockpile grade | 907 | 871 | -- | 871 |
| Nonstockpile grade | -- | 51 | -- | 51 |
| Total | 907 | 922 | -- | 922 |

[1] Defense Production Act (DPA) of 1950.
[2] Data may not add to totals shown because of independent rounding.

## DOMESTIC PRODUCTION

Mine production and shipments decreased 17% and 16%, respectively, compared with those of 1984. Production totaled 996 metric tons of tungsten content in 1984, the smallest amount since 1934, except for 1983. Shipments totaled 983 tons, the smallest amount since 1934. Although four mines in two Western States reported production, three mines provided more than 95% of the domestic tungsten production. No mine operated continuously. However, the Strawberry Mine and mill of Teledyne Tungsten, a subsidiary of Teledyne Inc., near North Fork, Madera County, CA, produced tungsten concentrate except during the winter, when it was closed owing to weather conditions.

The Climax Mine and mill of Climax Molybdenum Co., a division of AMAX Inc., at Climax, CO, produced tungsten at one-quarter capacity for most of the year. The Climax Mine, in Lake County, principally produces molybdenum.

The Pine Creek Mine and APT plant of Umetco Minerals Corp., a subsidiary of Union Carbide Corp., near Bishop, CA, was closed or operated at a reduced capacity during most of the year.

### Table 3.—Tungsten concentrate shipped from mines in the United States

| Year | Quantity | | Reported value, f.o.b. mine[1] | | |
|---|---|---|---|---|---|
| | Metric ton units of $WO_3$[2] | Tungsten content (metric tons) | Total (thousands) | Average per unit of $WO_3$ | Average per kilogram of tungsten |
| 1981 | 447,028 | 3,545 | $62,231 | $139.21 | $17.55 |
| 1982 | 198,652 | 1,575 | 22,062 | 111.06 | 14.00 |
| 1983 | 128,130 | 1,016 | 10,528 | 82.17 | 10.36 |
| 1984 | 147,958 | 1,173 | 13,409 | 90.63 | 11.43 |
| 1985 | 123,944 | 983 | 9,143 | 73.77 | 9.30 |

[1] Values apply to finished concentrate and are in some instances f.o.b. custom mill.

[2] A metric ton unit equals 10 kilograms of tungsten trioxide ($WO_3$) and contains 7.93 kilograms of tungsten.

### Table 4.—Major producers of tungsten concentrate and principal tungsten processors in the United States in 1985

| Company | Location of mine, mill, or processing plant |
|---|---|
| Producers of tungsten concentrate: | |
| Climax Molybdenum Co., a division of AMAX Inc | Climax, CO. |
| Teledyne Tungsten | North Fork, CA. |
| Umetco Minerals Corp., a subsidiary of Union Carbide Corp | Bishop, CA. |
| Processors of tungsten: | |
| AMAX Inc., AMAX Metals Group | Fort Madison, IA. |
| Fansteel Inc | North Chicago, IL. |
| General Electric Co | Euclid, OH, and Detroit, MI. |
| GTE Products Corp | Towanda, PA. |
| Kennametal Inc | Latrobe, PA, and Fallon, NV. |
| North American Philips Lighting Corp | Bloomfield, NJ. |
| Teledyne Firth Sterling | Pittsburgh, PA. |
| Teledyne Wah Chang Huntsville | Huntsville, AL. |

## CONSUMPTION

Domestic consumption of tungsten in primary products decreased 20% from that of 1984. The major end use, 62% of the total, continued to be in cutting and wear-resistant materials, primarily as tungsten carbide. Other end uses were mill products, 23%; specialty steels, 5%; and miscellaneous, including superalloys, welding and hard-facing rods, chemical and ceramic uses, and other tungsten materials, 10%.

Consumption of tungsten products used directly to make end-use items was distributed as follows: tungsten carbide powder, 63%; tungsten metal powder, 24%; scheelite, 5%; tungsten scrap, 3%; ferrotungsten, 2%; and other, 3%.

### Table 5.—Production, disposition, and stocks of tungsten products in the United States in 1985

(Metric tons of tungsten content)

| | Hydrogen-reduced metal powder | Tungsten carbide powder | | Chemicals | Other[1] | Total |
|---|---|---|---|---|---|---|
| | | Made from metal powder | Crushed and crystalline | | | |
| Gross production during year | 7,269 | 3,883 | 800 | 2,413 | 65 | 14,430 |
| Used to make other products listed here | 3,911 | 6 | 126 | 2,168 | -- | 6,211 |
| Net production | 3,358 | 3,877 | 674 | 245 | 65 | 8,219 |
| Producer stocks, Dec. 31 | 839 | 622 | 362 | 120 | 25 | 1,968 |

[1] Includes ferrotungsten, scheelite (produced from scrap), nickel-tungsten, and self-reducing oxide pellets.

### Table 6.—Consumption and stocks of tungsten products in the United States in 1985, by end use

(Metric tons of tungsten content)

| End use | Ferro-tungsten | Tungsten metal powder | Tungsten carbide powder | Scheelite (natural, synthetic) | Tungsten scrap[1] | Other tungsten materials[2] | Total |
|---|---|---|---|---|---|---|---|
| Steel: | | | | | | | |
| Stainless and heat-resisting | 34 | -- | -- | 42 | W | W | 76 |
| Alloy | 19 | -- | -- | W | W | W | 19 |
| Tool | 122 | -- | -- | 204 | W | W | 326 |
| Superalloys | W | W | W | W | W | 13 | 13 |
| Alloys (excludes steels and superalloys): | | | | | | | |
| Cutting and wear-resistant materials | -- | W | 5,033 | -- | W | W | 5,033 |
| Other alloys[3] | W | 7 | W | -- | 5 | W | 12 |
| Mill products made from metal powder | -- | 1,858 | W | -- | -- | W | 1,858 |
| Chemical and ceramic uses | -- | -- | -- | -- | -- | 85 | 85 |
| Miscellaneous and unspecified | 4 | 86 | 55 | 125 | 276 | 128 | 674 |
| Total | 179 | 1,951 | 5,088 | 371 | 281 | 226 | 8,096 |
| Consumer stocks, Dec. 31, 1985 | 36 | 31 | 990 | 28 | 61 | 60 | 1,206 |

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

[1] Does not include that used in making primary tungsten products.

[2] Includes melting base, self-reducing tungsten, tungsten chemicals, and others.

[3] Includes welding and hard-facing rods and materials and nonferrous alloys.

## PRICES

The average value of tungsten concentrate shipped from domestic mines and mills, as reported to the Bureau of Mines, decreased 19% to $73.77 per metric ton unit of $WO_3$, compared with the 1984 value. Excess tungsten concentrate was purchased from GSA during the year at prices ranging from $56.24 to $76.35 per metric ton unit for domestic use and from $61.16 to $67.52 per metric ton unit for export.

The following price quotations showed similar price trends: European prices of tungsten concentrate as reported in Metal Bulletin of London, the U.S. spot quotations as reported in Metals Week, and the International Tungsten Indicator. Differences in the monthly and annual averages resulted from differences between the scheelite and wolframite concentrate prices for the same period of time. For 1985, prices decreased 17%, compared with those for 1984.

Prices for intermediate products were not announced because of their competitiveness.

## Table 7.—Monthly price quotations of tungsten concentrate in 1985

| Month | Metal Bulletin (London), scheelite, European market, 70% $WO_3$ basis[1] | | | | Metal Bulletin (London), wolframite, European market, 65% $WO_3$ basis[2] | | | | Metals Week, U.S. spot quotations, 65% $WO_3$ basis, c.i.f. U.S. ports[3] | | | | International Tungsten Indicator, weighted average price,[4] 60% to 79% $WO_3$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dollars per metric ton unit | | | Dollars per short ton unit | Dollars per metric ton unit | | | Dollars per short ton unit | Dollars per short ton unit | | | Dollars per metric ton unit | Dollars per metric ton unit | Dollars per short ton unit |
| | Low | High | Average | Average | Low | High | Average | Average | Low | High | Average | Average | | |
| January | 79.63 | 82.63 | 81.13 | 73.60 | 66.38 | 71.38 | 68.88 | 62.49 | 60.00 | 70.00 | 65.38 | 72.06 | 80.61 | 73.13 |
| February | 79.00 | 82.00 | 80.50 | 73.03 | 71.00 | 75.00 | 73.00 | 66.22 | 61.00 | 69.50 | 66.50 | 73.30 | 76.16 | 69.09 |
| March | 79.00 | 82.00 | 80.50 | 73.03 | 73.78 | 77.67 | 75.73 | 68.70 | 66.00 | 70.00 | 67.75 | 74.68 | 77.70 | 70.49 |
| April | 77.50 | 80.50 | 79.00 | 71.67 | 72.63 | 76.13 | 74.38 | 67.48 | 63.50 | 69.00 | 67.13 | 73.99 | 76.86 | 69.73 |
| May | 74.88 | 78.13 | 76.51 | 69.40 | 65.75 | 70.25 | 68.00 | 61.69 | 57.00 | 66.00 | 62.20 | 68.56 | 77.57 | 70.37 |
| June | 69.38 | 73.75 | 71.57 | 64.92 | 59.75 | 66.13 | 62.94 | 57.10 | 55.00 | 63.00 | 59.00 | 65.04 | 73.16 | 66.37 |
| July | 69.00 | 74.00 | 71.50 | 64.86 | 60.33 | 68.78 | 64.56 | 58.56 | 52.50 | 59.00 | 55.75 | 61.45 | 69.79 | 63.31 |
| August | 69.00 | 75.00 | 72.00 | 65.32 | 64.50 | 70.63 | 67.57 | 61.29 | 54.00 | 66.00 | 61.40 | 67.68 | 69.68 | 63.21 |
| September | 69.00 | 75.00 | 72.00 | 65.32 | 66.13 | 72.25 | 69.19 | 62.77 | 59.00 | 67.50 | 64.06 | 70.62 | 68.29 | 61.95 |
| October | 67.89 | 74.00 | 70.94 | 64.36 | 62.56 | 69.89 | 66.22 | 60.08 | 56.00 | 62.50 | 59.25 | 65.31 | 70.28 | 63.76 |
| November | 65.56 | 71.67 | 68.62 | 62.25 | 58.67 | 66.56 | 66.62 | 56.80 | 53.00 | 61.50 | 57.45 | 63.33 | 68.99 | 62.59 |
| December | 62.00 | 70.00 | 66.00 | 59.87 | 55.86 | 63.86 | 59.86 | 54.30 | 48.00 | 59.00 | 53.88 | 59.39 | 68.60 | 62.23 |

[1] Low and high prices are reported semiweekly. Monthly averages are arithmetic averages of semiweekly low and high prices. The average price per metric ton unit of $WO_3$, which is an average of all semiweekly low and high prices, was $74.03 for 1985. The average equivalent price per short ton unit of $WO_3$ was $67.16 for 1985.

[2] Low and high prices are reported semiweekly. Monthly averages are arithmetic averages for semiweekly low and high prices. The average price per metric ton unit of $WO_3$, which is an average of all semiweekly low and high prices, was $67.61 for 1985. The average equivalent price per short ton unit of $WO_3$ was $61.33 for 1985.

[3] Low and high prices are reported weekly. Monthly averages are arithmetic averages of weekly low and high prices. The average price per short ton unit of $WO_3$, which is an average of all weekly low and high prices, excluding duty, was $61.69 for 1985. The average equivalent price per metric ton unit of $WO_3$ was $68.00 for 1985.

[4] Weighted average price per metric ton unit of $WO_3$ was $73.10 for 1985. The equivalent weighted average price per short ton unit of $WO_3$ was $66.31 for 1985.

## FOREIGN TRADE

Exports of tungsten in concentrate and primary products increased 58% from 1,700 tons in 1984 to 2,692 tons in 1985. Imports decreased 12%, from 8,092 tons in 1984 to 7,118 tons in 1985. Tungsten in concentrate had a net import decrease of 19%, from 5,678 to 4,622 tons, but tungsten in ammonium tungstate had a net import increase of 10%, from 1,164 to 1,279 tons. Other tungsten intermediate products had a net export increase of 229%, from 451 to 1,485 ounces.

### Table 8.—U.S. exports of tungsten ore and concentrate, by country

| | 1984 | | 1985 | |
|---|---|---|---|---|
| | Tungsten content (metric tons) | Value (thousands) | Tungsten content (metric tons) | Value (thousands) |
| Austria | 29 | $279 | 1 | $15 |
| Brazil | 25 | 161 | -- | -- |
| France | 6 | 93 | -- | -- |
| Germany, Federal Republic of | 48 | 571 | 10 | 85 |
| Ireland | ([1]) | 3 | -- | -- |
| Japan | -- | -- | 40 | 290 |
| Mexico | 21 | 133 | 18 | 108 |
| Netherlands | -- | -- | 54 | 323 |
| U.S.S.R. | -- | -- | 1 | 9 |
| United Kingdom | -- | -- | ([1]) | 1 |
| Total | 129 | 1,240 | 124 | 831 |

[1] Less than 1/2 unit.

Source: Bureau of the Census.

### Table 9.—U.S. exports of ammonium paratungstate, by country

| Country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Gross weight (metric tons) | Tungsten content[1] (metric tons) | Value (thousands) | Gross weight (metric tons) | Tungsten content[1] (metric tons) | Value (thousands) |
| Australia | ([2]) | ([2]) | $1 | -- | -- | -- |
| Belgium-Luxembourg | -- | -- | -- | 37 | 26 | $411 |
| Canada | 3 | 2 | 39 | 12 | 8 | 133 |
| France | 2 | 1 | 9 | 1 | 1 | 9 |
| Germany, Federal Republic of | 1 | 1 | 9 | 1 | 1 | 25 |
| Japan | ([2]) | ([2]) | 5 | -- | -- | -- |
| Mexico | -- | -- | -- | 5 | 4 | 51 |
| Netherlands | -- | -- | -- | 22 | 15 | 251 |
| Singapore | -- | -- | -- | ([2]) | ([2]) | 1 |
| South Africa, Republic of | 5 | 4 | 56 | -- | -- | -- |
| United Kingdom | -- | -- | -- | 24 | 17 | [illegible] |
| Total | 11 | 8 | 119 | 102 | 72 | 1,159 |

[1] Tungsten content estimated by multiplying gross weight by 0.7066.
[2] Less than 1/2 unit.

Source: Bureau of the Census.

## Table 10.—U.S. exports of tungsten carbide powder, by country

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Tungsten content (metric tons) | Value (thousands) | Tungsten content (metric tons) | Value (thousands) |
| Argentina | 8 | $285 | ([1]) | $11 |
| Australia | 2 | 161 | 3 | 87 |
| Austria | 48 | 973 | 32 | 787 |
| Belgium-Luxembourg | 15 | 396 | 25 | 511 |
| Brazil | 7 | 198 | 14 | 451 |
| Canada | 121 | 2,671 | 143 | 3,437 |
| Denmark | 8 | 205 | 8 | 297 |
| Finland | 1 | 27 | 10 | 174 |
| Germany, Federal Republic of | 38 | 902 | 71 | 1,629 |
| India | 1 | 48 | 5 | 117 |
| Ireland | 11 | 1,185 | 5 | 337 |
| Israel | ([1]) | 4 | 135 | 2,246 |
| Italy | 48 | 1,715 | 40 | 1,524 |
| Japan | 61 | 1,193 | 18 | 346 |
| Mexico | 14 | 439 | 17 | 627 |
| Netherlands | 6 | 367 | 15 | 640 |
| Peru | -- | -- | 1 | 15 |
| Philippines | 6 | 18 | -- | -- |
| Singapore | 2 | 47 | -- | 23 |
| South Africa, Republic of | -- | -- | 19 | 428 |
| Sweden | ([1]) | 1 | 3 | 38 |
| Switzerland | -- | -- | 10 | 189 |
| United Kingdom | 49 | 1,496 | 63 | 1,299 |
| Venezuela | 2 | 54 | 1 | 17 |
| Other | ([1]) | [r]30 | 23 | 504 |
| Total | 448 | 12,415 | 661 | 15,734 |

[r] Revised.

[1] Less than 1/2 unit.

Source: Bureau of the Census.

## Table 11.—U.S. exports of tungsten and tungsten alloy powder, by country

| Country | 1984 |  |  | 1985 |  |  |
|---|---|---|---|---|---|---|
|  | Gross weight (metric tons) | Tungsten content[1] (metric tons) | Value (thousands) | Gross weight (metric tons) | Tungsten content[1] (metric tons) | Value (thousands) |
| Australia | 7 | 6 | $121 | -- | -- |  |
| Austria | 23 | 19 | 400 | 23 | 19 | $525 |
| Belgium-Luxembourg | 5 | 4 | 109 | 6 | 5 | 135 |
| Brazil | 3 | 2 | 67 | 5 | 4 | 129 |
| Canada | 20 | 16 | 497 | 17 | 14 | 486 |
| Finland | 4 | 3 | 69 | 6 | 5 | 112 |
| Germany, Federal Republic of | 98 | 78 | 2,471 | 121 | 97 | 3,071 |
| Ireland | 4 | 3 | 104 | 1 | 1 | 27 |
| Israel | 520 | 416 | 8,880 | 1,172 | 937 | 21,567 |
| Italy | ([2]) | ([2]) | 1 | 4 | 3 | 260 |
| Japan | 61 | 49 | 1,834 | 12 | 10 | 496 |
| Mexico | 2 | 2 | 56 | 7 | 5 | 179 |
| Netherlands | 242 | 193 | 2,218 | 338 | 270 | 4,443 |
| Singapore | 3 | 3 | 64 | 6 | 4 | 101 |
| Switzerland | 1 | 1 | 62 | 21 | 17 | 222 |
| United Kingdom | 23 | 18 | 279 | 15 | 12 | 385 |
| Other | [r]4 | [r]3 | [r]97 | 57 | 46 | 1,193 |
| Total | 1,020 | 816 | 17,329 | 1,811 | 1,449 | 33,331 |

[r] Revised.

[1] Tungsten content estimated by multiplying gross weight by 0.80.

[2] Less than 1/2 unit.

Source: Bureau of the Census.

## Table 12.—U.S. exports of miscellaneous tungsten-bearing materials

| Product and country | 1984 Tungsten content (metric tons) | 1984 Value (thousands) | 1985 Tungsten content (metric tons) | 1985 Value (thousands) |
|---|---|---|---|---|
| Tungsten and tungsten alloy wire: | | | | |
| Argentina | 1 | $369 | (1) | $280 |
| Brazil | 7 | 1,161 | 5 | 879 |
| Canada | 19 | 3,179 | 22 | 3,561 |
| France | 2 | 356 | 1 | 236 |
| Germany, Federal Republic of | 7 | 1,462 | 6 | 1,601 |
| Hong Kong | 1 | 108 | 1 | 209 |
| India | 3 | 261 | 3 | 355 |
| Italy | 2 | 431 | 2 | 339 |
| Japan | 9 | 1,229 | 4 | 916 |
| Korea, Republic of | 2 | 297 | 3 | 339 |
| Mexico | 10 | 1,258 | 6 | 1,248 |
| Poland | 8 | 201 | 1 | 116 |
| Taiwan | 1 | 155 | 2 | 181 |
| U.S.S.R. | 6 | 446 | -- | -- |
| United Kingdom | 2 | 505 | 3 | 689 |
| Other | 2 | r1,019 | 3 | 1,106 |
| Total | 77 | 12,437 | 62 | 11,968 |
| Unwrought tungsten and alloy in crude form, waste, and scrap: | | | | |
| Australia | 7 | 55 | -- | -- |
| Austria | 77 | 347 | 61 | 487 |
| Belgium-Luxembourg | 128 | 1,106 | 56 | 451 |
| Canada | 28 | 422 | 33 | 550 |
| Finland | 1 | 19 | (1) | 4 |
| Germany, Federal Republic of | 219 | 1,611 | 287 | 2,090 |
| Ireland | 1 | 30 | -- | -- |
| Israel | 50 | 987 | 1 | 29 |
| Italy | 7 | 130 | 2 | 44 |
| Japan | -- | -- | 13 | 16 |
| Mexico | 1 | 11 | (1) | 18 |
| Netherlands | 28 | 227 | 37 | 303 |
| Saudi Arabia | 1 | 14 | 1 | 21 |
| South Africa, Republic of | 26 | 602 | -- | -- |
| Sweden | 2 | 20 | 3 | 53 |
| United Kingdom | 29 | 296 | 19 | 222 |
| Other | 1 | r22 | 1 | 12 |
| Total | 606 | 5,899 | 514 | 4,330 |
| Other tungsten metal: | | | | |
| Australia | 2 | 202 | 1 | 183 |
| Austria | 1 | 17 | (1) | 9 |
| Canada | 28 | 1,692 | 29 | 2,086 |
| France | 5 | 626 | 2 | 668 |
| Germany, Federal Republic of | 30 | 1,178 | 15 | 1,275 |
| Italy | 2 | 227 | (1) | 80 |
| Japan | 10 | 1,679 | 9 | 2,584 |
| Mexico | 8 | 260 | 4 | 627 |
| Netherlands | -- | -- | 9 | 177 |
| Singapore | 3 | 106 | (1) | 6 |
| South Africa, Republic of | -- | -- | 8 | 41 |
| Sweden | 1 | 49 | (1) | 4 |
| Switzerland | 6 | 305 | 1 | 297 |
| Taiwan | 2 | 150 | 1 | 103 |
| United Kingdom | 16 | 1,277 | 9 | 1,273 |
| Venezuela | 1 | 31 | (1) | 3 |
| Other | 2 | 309 | 1 | 536 |
| Total | 112 | 8,108 | 89 | 9,798 |
| Other tungsten compounds: | | | | |
| Austria | 2 | 77 | (1) | 21 |
| Belgium-Luxembourg | (1) | (1) | 3 | 68 |
| Brazil | 2 | 34 | 4 | 185 |
| Canada | 8 | 280 | 7 | 280 |
| China | -- | -- | 4 | 52 |
| France | 6 | 152 | 21 | 149 |
| Germany, Federal Republic of | 4 | 78 | 2 | 125 |
| Haiti | 19 | 60 | -- | -- |
| Hong Kong | (1) | 16 | 1 | 42 |
| Ireland | 6 | 148 | 2 | 87 |
| Israel | 75 | 1,340 | 1 | 52 |
| Italy | 2 | 91 | 2 | 107 |
| Japan | 10 | 201 | 5 | 179 |

See footnotes at end of table.

## Table 12.—U.S. exports of miscellaneous tungsten-bearing materials —Continued

| Product and country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Tungsten content (metric tons) | Value (thousands) | Tungsten content (metric tons) | Value (thousands) |
| Other tungsten compounds —Continued |  |  |  |  |
| Korea, Republic of | (1) | $2 | 54 | $117 |
| Mexico | 13 | 243 | 84 | 605 |
| Netherlands | 58 | 790 | 33 | 548 |
| Singapore | 11 | 323 | 8 | 299 |
| Sweden | 1 | 21 | -- | -- |
| United Kingdom | 1 | 25 | 1 | 172 |
| Venezuela | 1 | 24 | -- | -- |
| Other | 1 | r72 | 3 | 110 |
| Total | 220 | 3,977 | 235 | 3,198 |

rRevised.

[1] Less than 1/2 unit.

Source: Bureau of the Census.

## Table 13.—U.S. imports for consumption of tungsten ore and concentrate, by country

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Tungsten content (metric tons) | Value (thousands) | Tungsten content (metric tons) | Value (thousands) |
| Australia | 133 | $1,166 | 414 | $3,107 |
| Bolivia | 1,302 | 12,694 | 627 | 5,270 |
| Brazil | 149 | 1,309 | 69 | 503 |
| Burma | 341 | 2,545 | 55 | 643 |
| Canada | 1,464 | 12,645 | 1,371 | 10,364 |
| Chile | 9 | 161 | -- | -- |
| China | 31 | 221 | 558 | 3,391 |
| France | 16 | 140 | 4 | 36 |
| Germany, Federal Republic of | -- | -- | 24 | 213 |
| India | 7 | 56 | -- | -- |
| Japan | 10 | 92 | -- | -- |
| Korea, Republic of | 16 | 98 | -- | -- |
| Malaysia | 25 | 214 | 12 | 167 |
| Mexico | 196 | 1,610 | 183 | 1,325 |
| Peru | 605 | 5,258 | 282 | 2,093 |
| Portugal | 606 | 5,504 | 555 | 4,525 |
| Rwanda | 6 | 55 | 9 | 76 |
| Singapore | 13 | 90 | 87 | 797 |
| Spain | 22 | 220 | 11 | 124 |
| Thailand | 774 | 7,038 | 472 | 3,948 |
| Turkey | 51 | 422 | -- | -- |
| United Kingdom | 25 | 114 | -- | -- |
| Zaire | -- | -- | 13 | 124 |
| Zimbabwe | 6 | 63 | -- | -- |
| Total | 5,807 | 51,715 | 4,746 | 36,706 |

Source: Bureau of the Census.

### Table 14.—U.S. imports for consumption of ammonium tungstate, by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Tungsten content (metric tons) | Value (thousands) | Tungsten content (metric tons) | Value (thousands) |
| Australia | 44 | $466 | -- | -- |
| China | 720 | 8,275 | 1,126 | $13,229 |
| Germany, Federal Republic of | 26 | 397 | 33 | 449 |
| Hong Kong | 24 | 235 | 63 | 1,240 |
| Korea, Republic of | 356 | 3,999 | 116 | 1,391 |
| Netherlands | 2 | 42 | -- | -- |
| Taiwan | -- | -- | 12 | 132 |
| United Kingdom | (1) | (1) | 1 | 19 |
| Total | 1,172 | 13,414 | 1,351 | 16,460 |

[1] Less than 1/2 unit.

Source: Bureau of the Census.

### Table 15.—U.S. imports for consumption of ferrotungsten, by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Tungsten content (metric tons) | Value (thousands) | Tungsten content (metric tons) | Value (thousands) |
| Austria | 93 | $1,135 | 27 | $263 |
| Brazil | 26 | 319 | -- | -- |
| China | 8 | 90 | 22 | 219 |
| France | 10 | 115 | -- | -- |
| Germany, Federal Republic of | 38 | 425 | 1 | 12 |
| Netherlands | 8 | 92 | -- | -- |
| Portugal | 65 | 803 | 41 | 435 |
| Sweden | 32 | 369 | 2 | 22 |
| United Kingdom | 5 | 72 | -- | -- |
| Total | 285 | 3,420 | 93 | 951 |

Source: Bureau of the Census.

## Table 16.—U.S. imports for consumption of miscellaneous tungsten-bearing materials

| Product and country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Tungsten content (metric tons) | Value (thousands) | Tungsten content (metric tons) | Value (thousands) |
| **Other metal-bearing materials in chief value of tungsten:** | | | | |
| Brazil | -- | -- | 4 | $24 |
| China | -- | -- | 32 | 220 |
| Total | -- | -- | 36 | 244 |
| **Waste and scrap containing not over 50% tungsten:** | | | | |
| Canada | 1 | $5 | 1 | 5 |
| France | 3 | 30 | (1) | 8 |
| Portugal | 9 | 44 | -- | -- |
| United Kingdom | 13 | 135 | -- | -- |
| Other | (1) | 3 | 1 | 7 |
| Total | 26 | 217 | 2 | 20 |
| **Waste and scrap containing over 50% tungsten:** | | | | |
| Australia | 2 | 23 | (1) | 5 |
| Belgium-Luxembourg | 4 | 35 | 2 | 24 |
| Canada | 35 | 359 | 23 | 253 |
| China | 18 | 206 | 21 | 231 |
| France | 14 | 148 | 5 | 44 |
| Germany, Federal Republic of | 240 | 2,526 | 27 | 378 |
| Israel | 496 | 5,716 | 331 | 3,550 |
| Japan | 6 | 102 | 15 | 237 |
| Mexico | 1 | 9 | 10 | 106 |
| Netherlands | 131 | 782 | 125 | 617 |
| Singapore | 29 | 636 | 19 | 394 |
| South Africa, Republic of | 12 | 122 | 15 | 166 |
| Sweden | 48 | 518 | 12 | 142 |
| Switzerland | 2 | 31 | 6 | 82 |
| Thailand | 18 | 101 | -- | -- |
| United Arab Emirates | 2 | 17 | -- | -- |
| United Kingdom | 104 | 898 | 20 | 242 |
| Total | 1,162 | 12,229 | 631 | 6,471 |
| **Unwrought tungsten, except alloys, in lumps, grains, and powders:** | | | | |
| Belgium-Luxembourg | 4 | 50 | 1 | 42 |
| China | -- | -- | 5 | 45 |
| Germany, Federal Republic of | 14 | 431 | 17 | 461 |
| Japan | 3 | 79 | 3 | 122 |
| Korea, Republic of | 3 | 47 | 9 | 174 |
| United Kingdom | 2 | 40 | 5 | 37 |
| Other | (1) | 21 | 2 | 44 |
| Total | 26 | 668 | 42 | 925 |
| **Unwrought tungsten, ingots, and shot** | (1) | 5 | 2 | 45 |
| **Unwrought tungsten, other[2]** | (1) | 25 | 1 | 45 |
| **Unwrought tungsten, alloys:** | | | | |
| Austria | 14 | 190 | (1) | 17 |
| Canada | 6 | 368 | 2 | 149 |
| China | 38 | 760 | 7 | 184 |
| Germany, Federal Republic of | 19 | 425 | 17 | 365 |
| Korea, Republic of | 1 | 25 | -- | -- |
| Other | (1) | 31 | (1) | 12 |
| Total | 78 | 1,799 | 26 | 727 |
| **Wrought tungsten:[2]** | | | | |
| Austria | 7 | 542 | 9 | 987 |
| Belgium-Luxembourg | 12 | 932 | 6 | 501 |
| France | 4 | 28 | (1) | 110 |
| Israel | -- | -- | 11 | 390 |
| Japan | 9 | 1,788 | 25 | 2,853 |
| United Kingdom | 1 | 61 | 2 | 171 |
| Other | r5 | r402 | 3 | 222 |
| Total | 38 | 3,753 | 56 | 5,234 |
| **Tungstic acid:** | | | | |
| China | 192 | 1,742 | 158 | 1,148 |
| Other | 1 | 10 | (1) | 1 |
| Total | 193 | 1,752 | 158 | 1,149 |

See footnotes at end of table.

## Table 16.—U.S. imports for consumption of miscellaneous tungsten-bearing materials —Continued

| Product and country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Tungsten content (metric tons) | Value (thousands) | Tungsten content (metric tons) | Value (thousands) |
| **Calcium tungstate:** |  |  |  |  |
| Germany, Federal Republic of | 6 | $236 | 5 | $155 |
| Japan | 1 | 31 | ([1]) | 27 |
| Total | 7 | 267 | 5 | 182 |
| **Potassium tungstate** | -- | -- | 2 | 4 |
| **Sodium tungstate:** |  |  |  |  |
| China | -- | -- | 131 | 1,181 |
| Germany, Federal Republic of | ([1]) | 4 | 2 | 24 |
| Japan | -- | -- | 17 | 26 |
| Total | ([1]) | 4 | 150 | 1,231 |
| **Tungsten carbide:** |  |  |  |  |
| Australia | 2 | 24 | ([1]) | 7 |
| Austria | 1 | 31 | 4 | 115 |
| Belgium-Luxembourg | 33 | 921 | 37 | 1,075 |
| Canada | 2 | 74 | 1 | 29 |
| China | 4 | 98 | 50 | 1,020 |
| Germany, Federal Republic of | 317 | 6,551 | 257 | 5,726 |
| Japan | 2 | 53 | ([1]) | 6 |
| Korea, Republic of | 47 | 779 | 39 | 707 |
| South Africa, Republic of | 1 | 1 | -- | -- |
| United Kingdom | 42 | 695 | 31 | 495 |
| Other | ([1]) | 6 | 3 | 75 |
| Total | 451 | 9,233 | 422 | 9,255 |
| **Other tungsten compounds:** |  |  |  |  |
| Canada | 1 | 33 | ([1]) | 13 |
| China | -- | -- | 20 | 256 |
| Other | ([1]) | 18 | ([1]) | 33 |
| Total | 1 | 51 | 20 | 302 |
| **Mixtures, organic compounds: chief value in tungsten:** |  |  |  |  |
| Italy | 28 | 51 | -- | -- |
| Other | [r]4 | [r]118 | 7 | 227 |
| Total | 32 | 169 | 7 | 227 |

[r] Revised.

[1] Less than 1/2 unit.

[2] Estimated from reported gross weight.

Source: Bureau of the Census.

Table 17.—U.S. import duties on tungsten

| TSUS No. | Item | Rate of duty effective Jan. 1, 1985 | |
|---|---|---|---|
| | | Most favored nation (MFN) | Non-MFN |
| 601.54 | Tungsten ore | 17 cents per pound on tungsten content. | 50 cents per pound on tungsten content. |
| 603.45 | Other metal-bearing materials in chief value of tungsten. | 10 cents per pound on tungsten content and 4.8% ad valorem. | 60 cents per pound on tungsten content and 40% ad valorem. |
| 606.48 | Ferrotungsten and ferrosilicon tungsten | 6.9% ad valorem | 35% ad valorem. |
| 629.25 | Waste and scrap containing by weight not over 50% tungsten. | 5.6% ad valorem | 50% ad valorem. |
| 629.26 | Waste and scrap containing by weight over 50% tungsten. | 4.2% ad valorem | Do. |
| 629.28 | Unwrought tungsten, except alloys, in lumps, grains, and powders. | 12.1% ad valorem | 58% ad valorem. |
| 629.29 | Unwrought tungsten, ingots, and shot | 7.5% ad valorem | 50% ad valorem. |
| 629.30 | Unwrought tungsten, other | 8.6% ad valorem | 60% ad valorem. |
| 629.32 | Unwrought tungsten, alloys, containing by weight not over 50% tungsten. | 5.3% ad valorem | 35.5% ad valorem. |
| 629.33 | Unwrought tungsten, alloys, containing by weight over 50% tungsten. | 8.6% ad valorem | 60% ad valorem. |
| 629.35 | Wrought tungsten | 8.0% ad valorem | Do. |
| 416.40 | Tungstic acid | 11.6% ad valorem | 55% ad valorem. |
| 417.40 | Ammonium tungstate | 10.8% ad valorem | 49.5% ad valorem. |
| 418.30 | Calcium tungstate | 10.3% ad valorem | 43.5% ad valorem. |
| 420.32 | Potassium tungstate | 13.8% ad valorem | 50.5% ad valorem. |
| 421.56 | Sodium tungstate | 10.7% ad valorem | 46.5% ad valorem. |
| 422.40 | Tungsten carbide | 11.5% ad valorem | 55.5% ad valorem. |
| 422.42 | Other tungsten compounds | 10.5% ad valorem | 45.5% ad valorem. |
| 423.92 | Mixtures of two or more inorganic compounds in chief value of tungsten. | do | Do. |

## WORLD REVIEW

The Committee on Tungsten (COT) of the United Nations Conference on Trade and Development held a meeting in Geneva, Switzerland, during November in an effort to resolve a 22-year deadlock between producing and consuming countries concerning the stabilization of the world tungsten market. No agreement was reached by COT, but a sessional working group reviewed and assessed the current market situation and short-term outlook. Recommendations were made to complete studies of the scrap recycling industry in Japan and the United States, and to update previous studies on pricing indicators and trade in intermediate products.

**Australia.**—The two main mines in Australia, the King Island scheelite mine of Peko-Wallsend Ltd. and the Mount Carbine Mine of Wolfram Pty. Ltd., produced at about 50% of capacity each because of depressed world tungsten prices. Five of the six smaller Australian mines remained closed.

**Canada.**—The mine and mill operated by Canada Tungsten Mining Corp. Ltd. at Tungsten, Northwest Territories, produced 2,949 tons of tungsten in concentrate, the most from the mine since 1980 and the most of any mine in the market economy countries during 1985. Its shipments were 2,740 tons. Production capacity is 3,500 tons per year. Ore reserves at a grade of 1.24% totaled 14,000 tons at yearend. A large amount of lower grade ore is also present.

The Mount Pleasant tungsten-molybdenum mine and mill, in Charlotte County, New Brunswick, operated at a reduced capacity until it was forced to close in July because of depressed tungsten prices. The joint venture between Billiton Canada Ltd. and Brunswick Tin Mines Ltd. had an annual production capacity of 1,500 tons of tungsten in concentrate and 600 tons of molybdenite ($MoS_2$) from a 2,000-ton-per-day mill. Minable ore reserves were placed at 25,000 tons of tungsten in ore, grading 0.39% $WO_3$ and 0.204% $MoS_2$.

At yearend, AMAX through its subsidiary, AMAX of Canada Ltd., continued to delay development of the MacTung tungsten deposit near MacMillan Pass along the Yukon-Northwest Territories boundary until world tungsten market conditions improved. Reserves were placed at 57 million tons of ore, grading 0.95% $WO_3$ or 430,000 tons of tungsten, the largest known deposit in the market economy countries.

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[1] Physical scientist, Division of Ferrous Metals.

### Table 18.—Tungsten: World concentrate production, by country[1]

(Metric tons of tungsten content)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[p] |
|---|---|---|---|---|---|
| Argentina | 11 | 17 | 41 | 37 | 36 |
| Australia | 3,517 | 2,618 | 2,015 | 1,772 | 1,912 |
| Austria | [r]1,616 | [r]1,465 | 1,408 | 1,632 | 1,565 |
| Bolivia | 2,779 | 2,534 | 2,449 | 1,893 | 1,551 |
| Brazil | 1,576 | [r]1,524 | 1,026 | 1,037 | 1,175 |
| Burma | 825 | 844 | 930 | 1,096 | 945 |
| Canada | 1,993 | 2,842 | 328 | 3,715 | 3,100 |
| China[e] | 13,500 | 12,500 | 12,500 | 13,500 | 15,000 |
| Czechoslovakia[e] | 50 | 50 | 50 | 50 | 50 |
| France | 591 | 727 | 832 | 796 | [e]700 |
| India | 18 | 25 | 15 | 21 | 28 |
| Japan | 631 | 604 | 475 | 477 | 526 |
| Korea, North[e] | 2,200 | 2,200 | 500 | 1,000 | 1,000 |
| Korea, Republic of | 2,739 | 2,420 | 2,480 | 2,702 | 2,572 |
| Malaysia | 35 | 43 | 31 | 25 | [e]20 |
| Mexico | 263 | 194 | 186 | 274 | 291 |
| Mongolia[e] | 1,000 | 1,500 | 1,500 | 1,500 | 1,500 |
| New Zealand | 10 | 7 | 6 | 6 | 5 |
| Peru | 521 | [r]692 | 723 | 754 | 870 |
| Portugal | 1,395 | 1,358 | 1,183 | 1,493 | 1,751 |
| Rwanda | 281 | 324 | 231 | 291 | 310 |
| Spain | 437 | 545 | 517 | 565 | 530 |
| Sweden | 312 | 268 | 365 | 385 | 388 |
| Thailand | 1,209 | 855 | 562 | 741 | 586 |
| Turkey[e] | 153 | 150 | 325 | 350 | 350 |
| Uganda | 1 | 4 | 4 | [e]4 | [e]4 |
| U.S.S.R.[e] | 8,850 | 9,000 | 9,100 | 9,100 | 9,200 |
| United Kingdom | 50 | -- | -- | -- | -- |
| United States | 3,605 | 1,521 | 980 | 1,203 | 996 |
| Zaire | 46 | 38 | 44 | 30 | 18 |
| Zimbabwe | [e]55 | 52 | 15 | 29 | 10 |
| Total | [r]50,269 | [r]46,921 | 40,821 | 46,478 | 46,989 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Table includes data available through Aug. 8, 1986.

## Table 19.—Tungsten: World concentrate consumption, by country[1]

(Metric tons of tungsten content)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Reported consumption: | | | | | |
| Australia | 100 | 145 | 160 | [e]100 | 100 |
| Austria | 1,850 | 1,304 | 1,629 | 2,096 | 2,000 |
| Canada[e] [3] | 21 | 18 | 15 | 12 | 12 |
| France | [r]663 | [r]653 | 520 | 730 | 500 |
| Japan | 2,238 | 1,826 | 1,977 | 2,302 | 2,500 |
| Korea, Republic of | [r]1,898 | [r]1,742 | 1,555 | 2,070 | [4]2,048 |
| Mexico | [e]40 | 19 | 22 | [e]61 | 50 |
| Portugal | 227 | 183 | 174 | 159 | 150 |
| Sweden | 1,432 | 994 | 774 | 784 | 800 |
| United Kingdom | 879 | [r]660 | 560 | 610 | 600 |
| United States | 9,839 | 4,506 | 5,181 | 8,577 | [4]6,838 |
| Apparent consumption:[5] | | | | | |
| Argentina | 20 | 29 | 41 | [e]30 | 30 |
| Belgium-Luxembourg | 9 | [e]9 | [e]10 | 142 | 200 |
| Brazil | 480 | 454 | 450 | 593 | 550 |
| Bulgaria[e] [3] | 100 | 100 | 100 | 100 | 100 |
| China[e] [3] | [r]5,500 | [r]6,000 | 6,500 | 7,000 | 7,500 |
| Czechoslovakia[e] | 1,300 | 1,300 | 1,300 | 1,300 | 1,300 |
| German Democratic Republic[e] | 270 | 270 | 250 | 270 | 270 |
| Germany, Federal Republic of | 1,348 | 1,541 | 2,030 | 3,934 | 2,000 |
| Hungary[e] | 600 | [r]400 | 400 | 500 | 500 |
| India | 459 | 454 | [e]400 | [e]400 | 400 |
| Italy | [e]40 | [e]40 | 27 | 78 | 100 |
| Korea, North[e] [3] | 1,600 | 1,600 | 1,000 | 1,000 | 1,000 |
| Netherlands[e] | 400 | 300 | 300 | 300 | 400 |
| Poland | 427 | 1,312 | 1,073 | 594 | 1,000 |
| South Africa, Republic of[e] | 250 | 250 | 250 | 250 | 250 |
| Spain | [r]96 | 161 | 107 | 80 | 100 |
| U.S.S.R.[e] [3] | 15,900 | 15,900 | 15,900 | 16,000 | 16,000 |
| Total | [r]47,986 | [r]42,170 | 42,705 | 50,072 | 47,298 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Source, unless otherwise specified, is the Quarterly Bulletin of the UNCTAD Committee on Tungsten: Tungsten Statistics. V. 20, No. 1, Jan. 1986.

[2] In addition to the countries listed, Denmark, Finland, Israel, Norway, Romania, Switzerland, and Yugoslavia may consume small amounts of tungsten concentrate, but consumption levels are not reported, and available general information is inadequate to permit formulation of reliable estimates of consumption levels.

[3] Estimated by the Bureau of Mines.

[4] Reported figure.

[5] Production plus imports minus exports. For a few countries where data were available, variations in stocks were used in determining consumption.

# Vanadium

## By Peter H. Kuck[1]

For much of the vanadium industry in the market economy countries, 1985 was a difficult year. The industry continued to be hurt by its dependence on world steel production. Steel producers have been frustrated by a worldwide overcapacity situation since 1980. More than 85% of the vanadium sold on the world market was consumed in steelmaking as ferrovanadium or related vanadium-carbon ferroalloys. Numerous consumers of vanadium and several producers were affected by mergers or corporate restructuring. Rautaruukki Oy closed both of its vanadiferous magnetite mines in Finland because of unprofitability. Continued low prices for vanadium pentoxide ($V_2O_5$) forced prospective and past producers to delay or shelve plans for new mines and extraction facilities in North America and Oceania. The sharp decline of the South African rand against the U.S. dollar permitted Highveld Steel and Vanadium Corp. Ltd. and Transvaal Alloys Pty. Ltd. to escape most of the upheaval. Highveld commissioned its second iron plant in July and strengthened its position as the leading producer of vanadium in the face of domestic economic and political difficulties.

In July 1984, Union Carbide Corp. announced that it wanted to sell its Umetco Minerals Corp. subsidiary as part of its corporate restructuring program but was unable to find anyone willing to buy the entire operation. At the end of 1985, Union Carbide, faced with a hostile takeover bid from GAF Corp., decided to sell Umetco in parts. General Mining Union Corp. Ltd. (Gencor) agreed to purchase Umetco's chromium interests in the Republic of South Africa, while a Umetco employee group

**Table 1.—Salient vanadium statistics**

(Short tons of contained vanadium unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production: | | | | | |
| Ore and concentrate: | | | | | |
| Recoverable vanadium[1] | 5,126 | 4,098 | 2,171 | 1,617 | W |
| Value thousands | $71,496 | $52,577 | $30,675 | $24,551 | W |
| Vanadium oxides recovered from ore[2] | 6,368 | 4,867 | 2,483 | 2,620 | W |
| Vanadium oxides recovered from petroleum residue[3] | 1,900 | 1,513 | 898 | r1,701 | 2,695 |
| Consumption | 6,863 | 3,496 | 3,277 | 4,761 | 4,888 |
| Exports: | | | | | |
| Ferrovanadium (gross weight) | 435 | 326 | 775 | 469 | 454 |
| Ore and concentrate | 56 | 57 | 59 | 12 | 3 |
| Vanadium pentoxide, anhydride (gross weight) | 346 | 1,582 | 2,648 | 3,712 | 1,527 |
| Other compounds (gross weight) | 61 | 361 | 95 | 305 | 322 |
| Imports (general): | | | | | |
| Ferrovanadium (gross weight) | 1,236 | 855 | 346 | 1,461 | 977 |
| Ores, slags, residues | 2,435 | 1,112 | 58 | 633 | 303 |
| Vanadium pentoxide, anhydride | 354 | 129 | 408 | 149 | 63 |
| World: Production from ores, concentrates, slags | 38,562 | r36,124 | 30,924 | p34,291 | e 433,665 |

eEstimated. pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.

[1] Recoverable vanadium contained in uranium and vanadium ores and concentrates received at mills, plus vanadium recovered from ferrophosphorus derived from domestic phosphate rock.

[2] Produced directly from all domestic ores and ferrophosphorus; includes metavanadates.

[3] Includes vanadium recovered from ashes and spent catalysts.

[4] Excludes U.S. production.

took steps to acquire the subsidiary's vanadium and tungsten assets in the United States. These latter assets included the vanadium mill and open pit mine at Hot Springs, AR; the underground tungsten mines at Bishop, CA, and Tempiute, NV; and the vanadium and tungstan processing facility at Niagara Falls, NY. The employee group also wanted to purchase the vanadium mine and mill near Brits in the South African Transvaal Province. Gencor, Union Carbide's joint venture partner in Tubatse Ferrochrome (Pty.) Ltd., would acquire Umetco's 49% interest in Jagdlust Chrome Co. (Pty.) Ltd., Chrometco Minerals (Pty.) Ltd., and Chrome Corp. (South Africa) (Pty.) Ltd. The purchase of these South African operations would make Gencor a major force in the international ferroalloys industry, rivaling Middleburg Steel & Alloys Holdings (Pty.) Ltd. as one of the world's major ferrochromium producers. Union Carbide was negotiating with other organizations for the purchase of Umetco's tungsten interests in Brazil and Portugal, as well as its chromium mines and smelter in Zimbabwe.

In the United States, the beleaguered vanadium industry was completing a major restructuring in order to better compete in international markets against products derived from Chinese and South African magnetite ($Fe_3O_4$) ores. The restructuring was triggered by (1) the sharp decline in ferrovanadium consumption by U.S. steel producers during the 1982-83 recession, and (2) continuing depressed prices for coproduct uranium oxide. Umetco resumed full production of vanadium oxides at its Hot Springs mill in Arkansas to compensate for the shutdown of its uranium-vanadium operations on the Colorado Plateau. Atlas Corp., however, kept its Moab uranium-vanadium mill in Utah on standby and switched resources to the company's gold operations in Nevada. The uranium-vanadium industry was at a complete standstill throughout the first 8 months of 1985 because of the lowest spot market prices for yellowcake (natural $U_3O_8$ concentrate) in more than a decade. Only 43 uranium mines on the Colorado Plateau reported activity in 1985, compared with 198 mines in 1980. Several of the larger shippers in 1985 mined high-grade uraninite deposits with no significant vanadium mineralization.

The weak and slow recovery of the U.S. steel industry gave only minimal encouragement to the remaining hard-pressed producers and converters of vanadium oxides. The decelerating rise in ferrovanadium consumption represented a modest recovery from the 20-year low of 1983, rather than an overly optimistic outlook for the vanadium industry. Some ferrovanadium consumers remained concerned about the deteriorating sociopolitical situation in the Republic of South Africa. The first purchases of vanadium materials since 1961 for the National Defense Stockpile (NDS) were completed in August 1985.

**Domestic Data Coverage.**—Domestic production data for vanadium are developed by the Bureau of Mines from four voluntary surveys of U.S. mills and processing facilities. Of the 18 plants or mills canvassed in 1985, 17 responded. Supplemental information was provided by two power-generating stations. Data on uranium-vanadium mining operations are obtained from an independent survey conducted by the U.S. Department of Energy (DOE). Only 10 mines in the United States reported production or shipments of vanadium-bearing ores in 1984, compared with 35 in 1983 and more than 55 in 1982. In 1984, 26 uranium-vanadium mines on the Colorado Plateau permanently closed or were placed on standby because of the depressed market for yellowcake.

**Legislation and Government Programs.**—The program undertaken by the General Services Administration (GSA) in 1983 to upgrade and increase the stocks of vanadium materials held in the NDS was slowed by growing budgetary restrictions. The NDS goals of 1,000 short tons of vanadium contained in ferrovanadium and 7,700 tons of vanadium contained in $V_2O_5$ remained in effect throughout the year. These goals were established by GSA on May 1, 1980.

Contracts for a total of 180 tons of vanadium contained in pentoxide meeting Grade A purchase specifications were awarded to Gulf Chemical & Metallurgical Co. in 1983 and to Umetco in 1984. Grade A material must contain at least 98.0% $V_2O_5$ by weight on a dry basis and have a total alkali content of less than 0.75%. The grade is intended to be used as feed material for ferrovanadium conversion plants. The last lots, which contained 79 tons of vanadium, were accepted by GSA in August, bringing total receipts for 1985 to 112 tons. This completed the first large-scale acquisition of vanadium materials by the U.S. Government since the former Atomic Energy Commission halted its vanadium credits program in 1962.

As of December 31, 1985, the U.S. Government inventory consisted of 721 tons of contained vanadium in the form of $V_2O_5$. However, the 541 tons in the inventory that were purchased between 1947 and 1955 contain excessive amounts of alkali and may require upgrading prior to use. Because of recent advances in smelting and improvements in alloy quality, converters must now start with chemically purer grades of pentoxide.

The Interagency Working Group was established in 1982 to undertake quality assessment studies mandated by the National Materials and Minerals Policy, Research and Development Act of 1980. Both the National Academy of Sciences and the American Society for Metals (ASM) were advising the group. All of the stockpile purchase specifications and special instructions pertaining to vanadium were still being reviewed in 1985 by the Interagency Working Group. A joint industry and Government panel was formed by the U.S. Department of Commerce and ASM in December 1984 to specifically assess the quality of the $V_2O_5$ held in the NDS and recommend other suitable forms of vanadium for future acquisition.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, vanadium would be categorized in tier II and the existing goal would be lowered to 721 tons of vanadium metal equivalent. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

On September 25, the Secretary of Energy made a formal finding that the domestic uranium mining and milling industry was not viable in 1984. A significant fraction of the vanadium produced in the United States since 1950 has been a coproduct or byproduct of the uranium mined on the Colorado Plateau. Some analysts warned that continued closure of the plateau mines could increase this country's dependence on imports of vanadium from China and the Republic of South Africa. In conjunction with this finding, the Secretary (1) authorized the DOE to offer its enrichment customers a free variable tails assay option that, if exercised, would effectively spur domestic $U_3O_8$ sales, (2) postponed for 1 year a DOE plan to feed some of its own stockpiled uranium into the enrichment plants, and (3) asked the U.S. Trade Representative to carry out a 3-month study of uranium imports and their effect on the domestic uranium industry. According to the DOE Energy Information Administration, uranium imports totaled 16.4 million pounds of $U_3O_8$ in 1985, compared with 12.5 million pounds in 1984 and only 8.2 million pounds in 1983. Reported utility enrichment feed deliveries in 1984 were 20.6 million pounds of $U_3O_8$.[2] Unless current trends are reversed, uranium imports could account for more than 65% of all U.S. requirements by 1990. The U.S. Trade Representative's study was still in progress at the end of 1985.

Environmental concerns about the stabilization and long-term control of uranium-vanadium mill tailings continued to attract public attention in the Rocky Mountain States. At least three Federal agencies, a variety of State regulatory agencies, and most mill operators on the Colorado Plateau were involved in tailings stabilization projects, environmental hearings, and/or lengthy litigation.

The Environmental Protection Agency (EPA), the American Mining Congress, and the Environmental Defense Fund remained locked in litigation over EPA's final standards governing the long-term disposal of uranium mill tailings. EPA issued the standards in late 1983 under the authority of the Uranium Mill Tailings Radiation Control Act of 1978 (Public Law 95-604). To help alleviate this situation, the Nuclear Regulatory Commission (NRC) amended its existing regulations governing the disposal of uranium mill tailings so that they now conform with the 1983 standards (40 CFR, part 192) issued by the EPA. Under the revised regulations (10 CFR, parts 40 and 50), the earlier requirement for a minimum of 3 meters of cover over mill tailings to limit dispersal of radon has been replaced by the EPA's more stringent standards for longevity and radon control. The new NRC rules require that permanent mill tailings and waste disposal areas be designed so that they provide reasonable assurance of control of radiological hazards for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. The design must also provide reasonable assurance that releases of radon from the tailings to the atmosphere will not exceed an average of 20 picocuries per square meter per second. The new regulations, which took effect on November 15, should eliminate some of the legal inconsistencies and jurisdictional conflicts that have handicapped uranium-vanadium mill operators on the Colorado Plateau and should simplify long-range planning for the hard-pressed industry.

In early February, the families of 24 miners who developed cancer after working in southern Utah uranium mines were awarded almost $2 million in partial settlement of a court suit against Foote Mineral Co. of Exton, PA. The miners worked at the Vanadium Corp. of America (VCA) operations near Marysvale, UT, from 1949 to 1968. VCA was merged into Foote Mineral in 1967. Negligence claims were also brought against the Federal Government, which inspected the mines where high levels of radon-222 gas and its radioactive daughter products were observed. The plaintiffs held that the Government failed to warn the miners of the radiation dangers in the poorly ventilated uranium mines. However, a U.S. District Court judge ruled on July 1, 1985, that the Federal Government was immune from the claims of the Marysvale miners.

As of December 31, the Colorado Department of Health was still considering whether to grant Umetco a license permitting construction of a new tailings impoundment and disposal facility for the company's uranium-vanadium mill at Uravan, CO. The proposed disposal site would be on Spring Creek Mesa along the eastern side of the San Miguel River opposite Uravan. The licensing process has been complicated by an environmental suit brought by the State of Colorado against Umetco under the Resource Conservation and Recovery Act of 1976 (Public Law 94-580). Under an agreement signed with the Colorado Water Control Division in 1981, Umetco was required to halt its mill discharges into the existing ponds at Uravan by July 1, 1985. Extensive hearings on the tailings pond license and related environmental matters were held during the fourth quarter of 1984 in the neighboring towns of Montrose and Nucla. Approval reportedly has been blocked by concerns over (1) the thickness of the proposed clay lining for the new disposal facility, (2) protection of an apparently isolated pod of ground water beneath Spring Creek Mesa, and (3) the future reclamation of existing tailings piles at Uravan, some of which date back to the 1930's. Umetco was considering submitting a revised plan to the Colorado Department of Health that would allay specific concerns about potential ground water contamination. Umetco and the State of Colorado were exploring remedial action to permanently stabilize and control the existing tailings sites.

The Uravan mill was placed on standby in November 1984 because of the depressed uranium market. A month later, Umetco was forced to suspend vanadium recovery operations at its Rifle plant in Garfield County, CO. The Rifle plant depends upon the Uravan mill for its feedstocks of vanadium liquor.

## DOMESTIC PRODUCTION

Domestic production, expressed in terms of recovered vanadium, dropped back to the depressed level of 1983, the worst year for vanadium mining and milling operations since 1951. However, recoverable production, which represents receipts of ore and vanadium-bearing ferrophosphorus, was significantly higher than that of 1984. Arkansas was the leading producing State followed by Idaho. For the first time since 1907, no vanadium was recovered from the uraniferous sandstone ores of the Colorado Plateau. All five mills in Colorado and Utah that had coproduct vanadium recovery circuits were on standby during the first 8 months of 1985 because of the continuing depressed price for yellowcake and increased imports of uranium, both natural and enriched. Increased recovery of vanadium from petroleum residues, utility ash, and spent refinery catalysts partially compensated for the abnormally low level of domestic mine production.

During the first half of 1985, Umetco expanded operations at its mine and mill complex in Garland County, AR, to compensate for the closure of most of its smaller uranium-vanadium mines in Colorado and Utah. The Hot Springs mill, which has an annual capacity of approximately 7,500 tons of $V_2O_5$ equivalent, has traditionally used vanadiferous micaceous clays as its major feed material. The clays are mined from four open pits in the Wilson Springs carbonatite-alkalic igneous complex. In December, Umetco laid off 150 of 220 workers at the facility and suspended operations for at least 10 months because of high inventories. About 70 workers were retained to perform maintenance and upgrade the capabilities of the mill.

$V_2O_5$ and ammonium metavanadate ($NH_4VO_3$) were produced from vanadium-rich ferrophosphorus by Kerr-McGee Chemical Corp. at Soda Springs in Caribou County, ID. Vanadium-rich ferrophosphorus is a byproduct of two elemental phosphorus plants in Idaho and one in Montana. Increased demand for elemental phosphorus during the first half of 1985 led to a buildup of ferrophosphorus stocks in the two States.

FMC Corp. and the Shoshone Bannock Indian Tribes agreed in August to expand the Gay phosphate mine in Bingham County, ID, after 2-1/2 years of negotiations. The open pit mine, jointly operated by the J. R. Simplot Co. and FMC, is on the Fort Hall Indian Reservation about 30 miles northeast of Pocatello. The joint venture will be allowed to expand its mining operations into a 2,300-acre tract south of the present minesite in exchange for increased royalty payments to the tribes. Vanadium-bearing, furnace-grade phosphatic shale is being mined from the Meade Peak Member of the Permian Phosphoria Formation and shipped to FMC's electric furnaces west of Pocatello, where it is converted into elemental phosphorus. The ferrophosphorus slags made at FMC's elemental phosphorus operation have been a significant source of byproduct vanadium in recent years.

Phosphatic shale for the electric furnaces operated by the Monsanto Industrial Chemicals Co. at Soda Springs, ID, came from the company's nearby Henry Mine. Stauffer Chemical Co. shipped shale on the Union Pacific Railroad from its Wooley Valley Mine in Caribou County, ID, to its phosphorus plant at Silver Bow, MT.

Almost all of the uranium-vanadium mines in the Uravan Mineral Belt of western Colorado have been closed permanently or placed on standby as a result of the 1981-84 collapse of the domestic uranium ore market. Continued world overproduction of $U_3O_8$, the downturn in nuclear powerplant construction, and the discovery of high-grade uraninite deposits in the Canadian Province of Saskatchewan and South Australia all helped drag the price of natural uranium to a 12-year low in terms of constant dollars. The spot price of uranium concentrate (represented by Nuclear Exchange Corp.'s exchange value) bottomed out in April at $14.25 per pound of $U_3O_8$, a drop of $26.50 from the early 1980 price of $40.75. By yearend 1985, the spot price of uranium concentrate had partially recovered, returning to $17.00 per pound. This partial recovery encouraged two mills to reopen.

Cotter Corp. reopened its uranium-vanadium mill at Canon City, CO, in September, recalling 64 employees. The facility had been closed since January 1985 because of the depressed price for yellowcake. Approximately 33 employees were retained at that time to maintain the mill in standby condition, bringing present total employment to about 100. The mill has begun processing vanadium-poor, high-grade uraninite ore from the company's Schwartzwalder Mine, 9 miles northwest of Golden in Jefferson County. However, Cotter has no immediate plans to reactivate its vanadium recovery circuit at Canon City. In the past, feed liquors for the circuit have been produced from carnotite and tyuyamunite ores mined in the Uravan Mineral Belt.

In Garfield County, Umetco continued to ship $V_2O_5$ and $NH_4VO_3$ from stocks at its Rifle upgrading plant. Vanadium recovery operations were suspended at Rifle in December 1984 when vanadium liquor feedstocks supplied by the company's uranium-vanadium mill at Uravan were exhausted. The Uravan mill has been on standby since November 1984.

The White Mesa mill, a joint venture of Umetco (70%) and Energy Fuels Nuclear Inc. (30%), resumed operations on October 1. The 2,000-ton-per-day facility, 6 miles south of Blanding, UT, had been on standby since January 1983. Energy Fuels is supplying the mill with high-grade uraninite ore from its Hacks Canyon No. 2, Hacks Canyon No. 3, and Pigeon Mines in the Arizona Strip. The three mines produced a total of 175,000 tons of ore in 1985, averaging 0.60% $U_3O_8$. A few small independent mining operations in the Monticello, UT-Dove Creek, CO, area have also been shipping toll ores to White Mesa. Umetco is responsible for operation of the mill and currently employs 103 people, most of whom worked previously at either Blanding or the neighboring Umetco mill at Uravan, CO, which is still closed. White Mesa was scheduled to operate three full shifts per day, 7 days per week, until at least early 1987. The mill was expected to recover 5.7 million pounds of uranium and 2.5 million pounds of vanadium from 638,000 tons of ore between October 1985 and January 1987.

In a related action, Energy Fuels has agreed to supply the British Civilian Uranium Procurement Organization with more than 3 million pounds of yellowcake over a 10-year period starting in 1987. The new Kanab North Mine being developed by Energy Fuels in the Arizona Strip and the proposed Canyon Mine, south of the Grand Canyon near Tusayan, could provide White Mesa with additional uraninite.

Atlas sold 1,028,000 pounds of $V_2O_5$ in the 12 months preceding June 30, 1985, exhausting its vanadium inventory. The company kept its uranium-vanadium mill near Moab, UT, and its last three operating mines in San Juan County—the Pandora, the Velvet, and the Rim Columbus—on standby throughout all of 1985. However, the company stated that the mill and mines could be brought back into production within 6 to 8 weeks if the market for $U_3O_8$ improved. Atlas postponed development of its new uranium-vanadium mine near Ticaboo in Garfield County, UT, and instead sought financing to bring its newly discovered Gold Bar gold deposit in Eureka County, NV, into production. The expected profits from the Gold Bar property, which has an estimated 300,000 ounces of economically recoverable gold, could enable Atlas to keep its uranium-vanadium operations on standby for several years.[8]

On April 4, Homestake Mining Co. suspended conventional underground mining operations at its Section 23 uranium property near Ambrosia Lake, NM, laying off about 100 of its 275 employees. An additional 130 employees were released later in the year when the company's nearby Milan mill was placed on indefinite standby. The 3,400-ton-per-day mill had just reopened on January 2 with a throughput of 550 tons per day after a 4-month shutdown for inventory adjustment. The company continued to leach its abandoned stopes throughout the year. The Ambrosia Lake uranium operations were a significant source of byproduct vanadium sludge prior to 1982 when $V_2O_5$ prices were considerably higher in terms of constant dollars. At the peak of the 1980 uranium boom, Homestake's uranium operations had a total work force of 825 in New Mexico.

In recent years, vanadium-bearing feed materials of foreign origin have included iron slags from Chile, China, and the Republic of South Africa as well as utility ashes, spent catalysts from refineries, and a variety of petroleum residues. U.S. production from petroliferous materials in 1985 totaled 2,695 tons of contained vanadium, 58% more than the 1,701 tons (revised) for 1984.

Vanadium oxide concentrates were produced as a byproduct of the burning of Venezuelan and other Caribbean residual oils at a number of power-generating stations in the Eastern United States. Long Island Lighting Co. (LILCO) recovered high-grade ash containing 510 tons of $V_2O_5$, compared with 794 tons (revised) in 1984. The New York utility operated two oil-fired power stations in Suffolk County, one at Northport and the other at Port Jefferson. Recently, LILCO also has been supplying processors with an ash sludge recovered from its wastewater treatment plants that averages 15% to 16% $V_2O_5$ when dried. The lower grade material recovered in 1985 contained 403 tons of $V_2O_5$ and was 33% greater in gross weight than the 1984 material, which contained 314 tons of $V_2O_5$.

In January, Société d'Applications de la Chimie, de l'Electricité et des Métaux SA (SADACEM) and Société Européenne des Dérives du Manganese SA, two subsidiaries of the Société Générale de Belgique SA, acquired the spent catalyst processing facility of Gulf Chemical at Freeport, TX. The Texas plant recovers vanadium and molybdenum from spent hydroprocessing catalysts generated largely by oil refining and petrochemical industries in the Southern United States. The plant's products include fused flake $V_2O_5$, granular $V_2O_5$, various alkali vanadates, and purified molybdic oxide ($MoO_3$). The selling parent company, Associated Metals & Minerals Corp., retained Gulf Chemical's tin smelter at Texas City, TX, and a second catalyst processing facility at Ironton, OH, that has been idle for several years. The SADACI Div. of SADACEM produces approximately 1,300 tons (gross weight) per year of an 80% V grade of ferrovanadium as well as ferromolybdenum at its Langerbruggekaai ferroalloys plant near Ghent, Belgium.

The Freeport, TX, plant was a recent supplier of $V_2O_5$ to the NDS and is one of only three such reclamation facilities operating in the country. The facility, which employs 130 people, began operations in 1973 and is currently being expanded. The first phase of the expansion was completed in 1982, enabling the plant to treat up to 30,000 tons of catalysts per year. The new management plans to double this capacity by 1990 and eventually recover several million pounds of cobalt and nickel left in stockpiled catalyst residues.

At Freeport, TX, the spent catalysts are roasted with sodium carbonate ($Na_2CO_3$) in multiple-hearth furnaces for about 2 hours. The roasting is carried out under oxidizing conditions at temperatures ranging from 650° to 900° C. During the roasting, the vanadium and molybdenum react with the $Na_2CO_3$ to form soluble sodium salts. The resulting calcine is then quenched in water, ground, and leached. The pregnant leach liquor is separated from the insolubles with a counter-current decantation circuit. The pregnant leach liquor is next purified to remove phosphorus and alumina. The vanadium can then be separated from the molybdenum by precipitating the vanadium from solution with ammonium chloride. The $NH_4VO_3$ precipitate is later calcined and fused to produce $V_2O_5$. The residual molybdenum-laden liquor is finally heated to 80° to 85° C and acidified, with the molybdenum precipitated as molybdic acid ($H_2MoO_4 \cdot H_2O$). The $H_2MoO_4 \cdot H_2O$ precipitate is then calcined to produce $MoO_3$.[4]

In the second quarter, Hall Chemical Co. of Wickliffe, OH, awarded a preliminary engineering contract to Brown & Root U.S.A. for a similar plant that would recover vanadium and three other strategic metals from spent hydroprocessing catalysts. A feasibility study of the project was completed in late 1984 by the Chemical Engineering Div. of Brown & Root. For the past 5 years, pilot plant operations have been under way at Hall's inorganic chemical plant near Arab, AL. The new facility would have sufficient capacity to recover annually, in metal equivalent units, 3 million pounds of vanadium, 5 million pounds of molybdenum, 2.3 million pounds of nickel, and 650,000 pounds of cobalt.

The dismal situation of U.S. producers of ferrovanadium and proprietary vanadium-iron-carbon alloys improved somewhat in 1985. Although demand for ferrovanadium was essentially unchanged from that of 1984, U.S. imports of the ferroalloy declined by one-third. The three traditional producers of ferrovanadium—Foote Mineral, Shieldalloy Corp., and Umetco—also profited to some extent from the closure and sale in early 1984 of Engelhard Corp.'s aluminothermic reduction plant at Strasburg, VA. Affiliated Metals and Minerals Inc. attained full production capability at its new specialty ferroalloys plant in Newcastle, PA. The Newcastle plant is currently producing low-aluminum, high-purity 80%, standard 80%, 60%, and 42% grades of ferrovanadium as well as ferromolybdenum, molybdenum briquets, and ferroboron.

On October 16, Cabot Corp. announced plans to restructure its business groups and sell most of its specialty metals and alloying operations in order to improve the company's financial performance. The proposed divestiture would include a titanium rolling mill and superalloy production facilities at Kokomo, IN; a titanium tubing plant at Arcadia, LA; beryllium-copper alloy production facilities at Elkhart, IN, and Reading, PA; and the aluminum master alloy plants at Henderson, KY, and Wenatchee, WA. However, the company would retain its integrated tantalum and columbium production facilities in Pennsylvania. The divestiture would reduce Cabot's present work force from 7,700 to less than 5,700. Cabot produces 2.5% vanadium aluminum, 5% vanadium aluminum, and 3% zirconium-2% vanadium aluminum at the Henderson and Wenatchee plants.

Producers of primary vanadium chemicals included Foote Mineral, Cambridge, OH; Stauffer, Weston, MI; and Umetco, Niagara Falls, NY. Vanadium oxytrichloride ($VOCl_3$) and vanadium tetrachloride ($VCl_4$) were the two ranking chemicals after pentoxide.

In March, Chesebrough-Pond's Inc., a diversified consumer products company, acquired Stauffer for $1.25 billion through a cash tender offer of $28 per share for Stauffer common stock. Stauffer's 14 operating divisions were consolidated into 4 divisions, which form the nucleus of Chesebrough-Pond's new Chemical Products Group. Stauffer's basic research capability was expected to complement Chesebrough-Pond's marketing skills and organization. Stauffer, a producer of basic, agricultural, and specialty chemicals, synthesizes vanadium catalysts as a sideline at its Weston, MI, plant. Products include vanadium trichloride ($VCl_3$), $VCl_4$, $VOCl_3$, and vanadium tris-acetylacetonate ($V(C_5H_7O_2)_3$). Stauffer also operates the elemental phosphorus plant at Silver Bow, MT, which produces a byproduct vanadium-rich ferrophosphorus.

**Table 2.—Mine production and recoverable vanadium of domestic origin produced in the United States**

(Short tons of contained vanadium)

| Year | Mine production[1] | Recoverable vanadium[2] |
|---|---|---|
| 1981 | 5,852 | 5,126 |
| 1982 | 4,093 | 4,098 |
| 1983 | W | 2,171 |
| 1984 | W | 1,617 |
| 1985 | W | W |

W Withheld to avoid disclosing company proprietary data.

[1] Measured by receipts of uranium and vanadium ores and concentrates at mills, vanadium content.

[2] Recoverable vanadium contained in uranium and vanadium ores and concentrates received at mills, plus vanadium recovered from ferrophosphorus derived from domestic phosphate rock.

**Table 3.—U.S. production of vanadium oxides[1]**

(Short tons)

| Year | Gross weight | Oxide content[2] |
|---|---|---|
| 1981 | 11,366 | 11,367 |
| 1982 | 8,850 | 8,689 |
| 1983 | 4,590 | 4,344 |
| 1984 | 4,688 | 4,678 |
| 1985 | W | W |

W Withheld to avoid disclosing company proprietary data.

[1] Produced directly from all domestic ores and ferrophosphorus; includes metavanadates.

[2] Expressed as equivalent $V_2O_5$.

## CONSUMPTION, USES, AND STOCKS

Reported domestic consumption of vanadium in 1985 was only about 3% higher than that of 1984. This meager rise in consumption represented a slowing of the recovery from the 20-year low of 1983 and gave little hope for substantial improvement in the immediate future. The primary cause of the recovery to date has been increased domestic production of vanadium-bearing, high-strength, low-alloy (HSLA) steels for the construction and automotive industries. The steel industry as a whole showed an overall decline of 4.6% in raw steel output from the encouraging level of 1984, and remained in an uphill battle against near-record-high imports of major iron and steel products, a still strong but weakening dollar, and low profitability. Import penetration of steel mill products again exceeded 25% despite voluntary restraint agreements between the United States and 15 of its larger trading partners.

Approximately 83% of the vanadium was consumed by the domestic iron and steel industry as ferrovanadium, related vanadium-carbon ferroalloys, or a new proprietary product called Vanox. Vanox, a specially processed form of vanadium trioxide introduced by Umetco in 1984, is designed primarily for addition to tool steel and can be added directly to the argon-oxygen-decarburization vessel. $V_2O_5$ cannot be substituted for the trioxide because the melting point of the pentoxide (690° C) is lower than that of either the steel (1,550° to 1,650° C) or the trioxide (1,970° C). The trioxide is easier to reduce than the pentoxide and is more homogeneously distributed throughout the melt. At least eight domestic specialty steel producers were using or evaluating Vanox.

The dependence of the vanadium industry on the struggling iron and steel industry continued to create marketing problems for the five domestic producers of ferrovanadium. Ferrovanadium imports slackened from the record high of 1984, but remained a serious problem for the hard-pressed producers. Converters in Austria and Belgium-Luxembourg increased their share of the U.S. ferrovanadium market at the expense of Canada. Marketing was complicated further because the South African producers resumed shipments of the ferroalloy after a hiatus of 7 years. A significant increase in consumption of ferrovanadium and other vanadium-iron-carbon additives by producers of carbon steel offset decreased consumption in HSLA steel. A large part of the decrease in the HSLA steel category between 1984 and 1985 reflected the depressed conditions in the oil country tubular goods market. Demand for ferrovanadium by tool steel producers also deteriorated significantly. Total shipments of sheet steel and strip to the automotive industry and other consumer goods sectors were essentially unchanged. However, shipments of structural shapes did improve significantly.

The restructuring of the U.S. steel industry continued throughout 1985. The loss of over $6 billion between 1982 and 1984 triggered a string of steel company mergers, modernization programs, and permanent closures of obsolete plants. Production costs have been cut more than 10% since 1982, and labor productivity has improved dramatically. The two giants, United States Steel Corp. (USS) and Bethlehem Steel Corp., have discarded more than one-third of their 1979 capacities. According to the American Iron and Steel Institute, domestic steel producers have shut down more than 600 steelworks and fabrication plants since 1974.

Despite all these changes, the industry lost an additional $1.7 billion in 1985. USS and Armco Inc. were the only two of the six leading integrated steelmakers to make a profit during the year. These new losses led to another round of plant closures and sales. Inland Steel Co., for example, announced plans to close seven outdated open-hearth furnaces at its Indiana Harbor Works in East Chicago, IN. LTV Steel Co. idled indefinitely numerous facilities at Aliquippa, PA, Chicago, IL, Gulfport, MS, and Pittsburgh, PA. This radical restructuring, coupled with recent investments in continuous casters, continuous annealing lines, and other new equipment should lead to a smaller, more productive industry. At least seven continuous casters were being planned or installed. One of the highlights of the year was the startup of The Timken Co.'s new $500 million alloy steel plant at Faircrest, OH. The technological changes accompanying these modernization programs should have a positive effect on the long-term outlook for vanadium.

Demand for vanadium in titanium alloys was about 12% lower than that of 1984. The B-1B bomber program and increased production of other military aerospace products have helpod initiate perhaps the most stable period in the 35-year history of the titanium industry. The U.S. aerospace industry currently depends on Government orders for approximately two-thirds of its total business. However, all of the budgeted bombers have now been ordered, with the 100th bomber scheduled for delivery in June 1988. Shipments of titanium mill products to domestic aircraft manufacturing plants slowed considerably toward the end of the year despite a surge in commercial aircraft orders. The Boeing Co. alone booked orders for 364 airliners, the highest figure since it won 461 orders in 1978. The total value of Boeing's 364 orders was about $14 billion. According to the Aerospace Industries Association, Boeing, Lockheed Corp., and McDonnell Douglas Corp. together shipped a total of 271 civil jet transport aircraft in 1985, compared with only 182 in 1984 and 257 in 1983.

Ti-6Al-4V alloy, which has been used in jet engines, airframes, and other aircraft parts for more than two decades, accounted for more than one-half of the titanium-based alloy market in 1985. Relatively small amounts of Ti-8Al-1V-1Mo and Ti-3Al-2.5V were being used for some jet engine components, while two newer alloys, Ti-15V-3Cr-3Al-3Sn and Ti-10V-2Fe-3Al, were being extensively evaluated for the next generation of commercial airliners. Forgings of Ti-10V-2Fe-3Al have already been used in some components of the Boeing 757 and 737-300 jetliners. The forgeability characteristics of Ti-10V-2Fe-3Al are reportedly superior to those of any other known titanium alloy. The newly formed Titanium Development Association has been focusing a large part of its initial efforts on developing new markets for titanium alloys in the oil, gas, and petrochemical industries. Ti-3Al-8V-6Cr-4Mo-4Zr, for example, has excellent corrosion resistance to saltwater saturated with hydrogen sulfide and may be superior to the nickel-based alloys that are currently used when a sour gas environment is encountered in oilfield operations. The association has also identified potential markets for titanium mill products in the shipbuilding, automotive, paper, and medical equipment industries.

In August, Armco agreed to sell its Aerospace and Strategic Materials Group to Owens-Corning Fiberglas Corp. of Toledo, OH, for $415 million in cash. Armco, a major steelmaker with headquarters in Middletown, OH, had been forced earlier to halt its diversification efforts and adopt a retrenchment strategy because of setbacks in its once highly profitable seamless pipe business. The sale of the aerospace group was completed in September, giving Owens-Corning control of the Hitco Fabricated Compesites Div., the Hitco Materials Div., and the Ladish Co., as well as an 80% stake in the Oregon Metallurgical Corp. (Oremet). The other 20% of Oremet is publicly held.

Oremet is the third largest titanium sponge producer in the United States and a major consumer of vanadium-aluminum master alloys. Oremet currently employs 365 workers at its Albany, OR, metallurgical complex and has been making titanium-aluminum-vanadium alloys for over 20 years. Ladish, of Cudahy, WI, produces custom aerospace and high-performance industrial forgings along with stainless steel piping components for the power generation and petrochemical industries. According to analysts, Owens-Corning bought Armco's aerospace group primarily to acquire the two Hitco divisions, which are leading suppliers of carbon fibers, epoxy resins, and preimpregnated fabrics for advanced composites.

Plans for a leveraged buyout of the Timet Div. of Titanium Metals Corp. of America (TMCA) by a Timet management group were shelved in late November. Timet is the largest producer of titanium alloys and metal in the United States and operates a 14,000-ton-per-year sponge plant at Henderson, NV. Allegheny International Inc. and NL Industries Inc., joint owners of TMCA, said that although the outlook for the titanium metal market was favorable, they would continue to seek a buyer for the Timet Div. as part of their new divestiture strategy. Top Timet executives and Kelso & Co., a New York management consulting firm, which was arranging financing in return for a share in the company, had agreed in January to purchase the division. However, the management group was unable to arrange financing, partly because of lower-than-anticipated projected sales volume and profits for the division.

Consumption of $NH_4VO_3$, granular pentoxide, and other vanadium chemicals for catalysts dropped back to the depressed levels of 1983, and remained far below the average of the last decade. Sulfuric acid production, a major end use for vanadium oxidation catalysts, approximated that of 1984. More than 80% of the sulfuric acid currently being produced in the United States is synthesized by the contact process, which uses an 8% $V_2O_5$ catalyst on a silica support to convert the sulfur dioxide to sulfur trioxide. Vanadium catalysts are also used in the commercial synthesis of three key organic intermediates: maleic anhydride, adipic acid, and phthalic anhydride. Production of maleic anhydride increased only 4% in 1985, while production of adipic acid and phthalic anhydride declined 7% and 4%, respectively. In November, Monsanto Industrial Chemicals permanently closed its 110-million-pound-per-year benzene-based maleic anhydride unit in St. Louis, MO, after raising the capacity of its new butane-based unit at Pensacola, FL, from 130 million to 190 million pounds per year. The butane process employs a new proprietary vanadium catalyst that has a higher $V_2O_5$ content than the previous $2V_2O_5 \cdot MoO_3$ benzene catalyst.

In addition to the consumers' stocks, producers' stocks of vanadium as fused oxide, precipitated oxide, vanadates, metal, alloys, and chemicals totaled 2,849 tons of contained vanadium at yearend 1985, compared with 3,321 tons at yearend 1984.

### Table 4.—Producers of vanadium alloys or metal in the United States in 1985

| Producer | Plant location | Products[1] |
|---|---|---|
| Affiliated Metals and Minerals Inc | New Castle, PA | FeV. |
| Cabot Corp., Engineered Products Group | Henderson, KY | VAl and ZrVAl. |
| Do | Wenatchee, WA | Do. |
| Foote Mineral Co., Ferroalloys Div | Cambridge, OH | FeV and Ferovan.[2] |
| Metallurg Inc., Shieldalloy Corp | Newfield, NJ | FeV. |
| Reading Alloys Inc | Robesonia, PA | FeV and VAl. |
| Teledyne Inc., Teledyne Wah Chang Albany Div | Albany, OR | V. |
| Union Carbide Corp., Umetco Minerals Corp | Marietta, OH[3] | Carvan[2] and Nitrovan.[2] |
| Do | Niagara Falls, NY | FeV and VAl. |

[1] FeV, ferrovanadium; V, vanadium metal; VAl, vanadium aluminum; ZrVAl, zirconium vanadium aluminum.

[2] Registered trademarks for proprietary products.

[3] Elkem Metals Co. has been toll converting vanadium oxide at Marietta for Union Carbide since 1981.

### Table 5.—U.S. consumption and consumer stocks of vanadium materials, by type

(Short tons of contained vanadium)

| Type | 1984 | | 1985 | |
|---|---|---|---|---|
| | Consumption | Ending stocks | Consumption | Ending stocks |
| Ferrovanadium[1] | 3,826 | 334 | 4,071 | 248 |
| Oxide | 26 | W | 18 | 5 |
| Ammonium metavanadate | W | W | W | W |
| Other[2] | 909 | 115 | 794 | 107 |
| Total | 4,761 | 449 | 4,883 | 360 |

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1] Includes other vanadium-iron-carbon alloys as well as vanadium oxides added directly to steel.

[2] Consists principally of vanadium-aluminum alloy, plus relatively small quantities of other vanadium alloys and vanadium metal.

### Table 6.—U.S. consumption of vanadium in 1985, by end use

(Short tons of contained vanadium)

| End use | Quantity |
|---|---|
| Steel: | |
| Carbon | 1,135 |
| Stainless and heat-resisting | 85 |
| Full alloy | 944 |
| High-strength, low-alloy | 1,333 |
| Tool | 522 |
| Unspecified | W |
| Total | 4,019 |
| Cast irons | 22 |
| Superalloys | 16 |
| Alloys (excluding steels and superalloys): | |
| Cutting and wear-resistant materials | W |
| Welding and alloy hard-facing rods and materials | 5 |
| Nonferrous alloys | 788 |
| Other alloys[1] | W |
| Chemicals and ceramics: | |
| Catalysts | 14 |
| Other[2] | W |
| Miscellaneous and unspecified | 19 |
| Grand total | 4,883 |

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

[1] Includes magnetic alloys.

[2] Includes pigments.

## PRICES

The Metals Week price quotation for domestic 98% fused $V_2O_5$ (metallurgical-grade) at the beginning of 1985 was $3.35 to $3.65 per pound of $V_2O_5$, f.o.b. mill. This price spread was established on May 15, 1981, and remained in effect throughout all of 1985. The slowing of demand for ferrovanadium gave little encouragement to domestic pentoxide producers, struggling to recover from the 1982-83 recession. Some discounting of metallurgical-grade material continued throughout 1985 because of the strong but weakening dollar and downstream pressure from imports of ferrovanadium.

Prices for metallurgical-grade pentoxide in Japan and Western Europe firmed during the first half of 1985 owing to increased production of ferrovanadium by major converters and production constraints on exports of pentoxide from China. Throughout the year, Highveld maintained its list price of $2.41 per pound of $V_2O_5$ c.i.f. for 98% minimum fused pentoxide from the Republic of South Africa. The European spot price for metallurgical-grade material increased from $2.30 to $2.35 per pound in early January to a high in March and April of $2.37 to $2.42. The spot price weakened during the second half of the year, reaching a low of $2.05 to $2.15 in November and eventually closed at $2.15 to $2.20.

The Metals Week price spread for technical air-dried $V_2O_5$ (chemical-grade) of $4.10

to $4.94 per pound of $V_2O_5$ was set on April 1, 1982, and remained unchanged throughout 1985.

On July 8, Umetco, facing probable divestiture and under pressure from continuing high imports of ferrovanadium, lowered prices for its 60% and 80% standard grades of ferrovanadium as well as Carvan to $5.00 per pound of contained vanadium, f.o.b. Niagara Falls, NY. This move to maintain market share triggered a series of price reductions between July 12 and August 1 by other domestic producers. The end results of the price reductions are presented in the following tabulation:

| Company and product | Price per pound of contained vanadium | |
|---|---|---|
| | Jan. 1, 1985 | Dec. 31, 1985 |
| Foote Mineral Co.: | | |
| Ferovan | $6.25 | $5.00 |
| 70% to 80% FeV | 6.50 | 5.00 |
| Shieldalloy Corp.: | | |
| Standard 60% to 70% FeV | 6.25 | 5.00 |
| Umetco Minerals Corp.: | | |
| Carvan | 6.00 | 5.00 |
| UCAR 80% FeV | 6.50 | 5.00 |

The $5 domestic price effectively undercut spot dealer quotes for imported ferrovanadium, which reportedly ranged from $5.20 to $5.50 during the third quarter, and encouraged several traders to seek more profitable markets in Europe.

Previously, in mid-1984, Umetco took action to protect its market share against imported ferrovanadium with the introduction of Vanox. The new proprietary oxide product was priced initially at $5.05 per pound of contained vanadium, f.o.b. Niagara Falls, NY, and was expected to compete in the tool steel additive market against the more expensive, imported ferrovanadium. The July 8 price reductions necessitated a lowering of the Vanox price. At yearend 1985, Vanox was being quoted at $4.50 per pound of contained vanadium, to be effective with January 2, 1986, shipments.

## FOREIGN TRADE

The U.S. trade pattern for vanadium products has changed dramatically since 1981. The United States is no longer a net exporter of ferrovanadium and has begun to purchase substantial amounts of the 80% grade from the European Communities and Austria. At the same time, U.S. exports of $V_2O_5$ have increased more than threefold, while imports of the oxide have plummeted. This shift in the pentoxide trade pattern has been magnified because imports of vanadium trioxide from the Republic of South Africa have replaced some of the more conventional pentoxide imports. It is also important to note that significant amounts of exported pentoxide were apparently in the form of oxidation catalysts.

The strong dollar and stiff competition from European converters continued to hurt U.S. export sales of vanadium-iron-carbon alloys. Exports of ferrovanadium totaled 454 tons gross weight, compared with 469 tons for 1984 and 775 tons for 1983. The average declared value of the ferrovanadium was $5.28 per pound of alloy, a 5% decrease from the $5.55 value for 1984. The modest increase in domestic ferrovanadium production from the highly depressed levels of 1982 and 1983 gave little encouragement to beleaguered U.S. pentoxide producers. This frustrating situation coupled with the effects of a falling South African rand[8] kept the pressure on U.S. producers to compete agressively against South African material in Western Europe, Canada, and Japan. In the fourth quarter, the decline of the dollar against the deutsche mark and a temporary reduction in sales of Chinese pentoxide to Europe offered some relief to U.S. exporters of both pentoxide and ferrovanadium. Exports of anhydride and catalysts containing pentoxide totaled only 1,527 tons gross weight, a 59% decrease from the 3,712 tons for 1984. According to the Bureau of the Census, $VCl_4$ was one of the principal unspecified chemicals exported in 1985.

U.S. imports for consumption of ferrovanadium dropped to 779 tons of contained vanadium from a historical high of 1,171 tons in 1984. The material averaged 80.6% vanadium and had a mean Customs value of $4.98 per pound of contained vanadium. This decrease in imports reversed, at least temporarily, a long-term trend in which European converters have been gradually capturing a larger share of the U.S. ferrovanadium market. Imports accounted for 19% of reported consumption of vanadium-iron-carbon alloys, compared with less than 4% in 1973. The Belgium-Luxembourg Economic Union replaced Canada as the principal source of imported ferrovanadium and accounted for 27% of the imported alloy in terms of contained weight. Imports of Canadian ferrovanadium fell from a record high in 1984 to their lowest level in 7 years.

Only 20 tons gross weight of pentoxide was imported in 1985. More than 90% of this material came from the Federal Republic of Germany. For the second year in a row, there were no imports of pentoxide reported for consumption from the Republic of South Africa. Between 1978 and 1983, annual imports of South African pentoxide steadily declined from 1,152 tons to 56 tons.

Imports of vanadium contained in ores, slags, and residues totaled only 303 tons, compared with 633 tons in 1984. At least 45% of this vanadium came directly or indirectly from the refining operations of Petróleos de Venezuela S.A. (PDVSA), the state oil monopoly of Venezuela. The remaining 55% was contained in other assorted petroleum refinery residues and utility ashes from, in order of decreasing tonnage, Italy, the Netherlands Antilles, Mexico, Suriname, Jamaica, and Barbados. Part of the Caribbean material also may have been recovered from Venezuelan crude. For only the second time in 18 years, there were no imports of vanadiferous iron slag from Highveld's Witbank steelworks in the Transvaal, Republic of South Africa.

Potassium vanadate imports amounted to 57 tons gross weight, of which 38 tons came from the Republic of South Africa and 19 tons came from the Federal Republic of Germany. In addition, 15 tons of $NH_4VO_3$ was received from the United Kingdom. Imports of vanadium carbide and unwrought vanadium metal were less than 1 ton each. Imports classified as "Other vanadium compounds" totaled 807 tons gross weight, compared with 831 tons in 1984. As mentioned earlier, 97% of this material was vanadium trioxide from the Republic of South Africa. Nearly all of the remaining 23 tons was unspecified chemicals from the United Kingdom.

### Table 7.—U.S. exports of vanadium in 1985, by country

(Thousand pounds and thousand dollars)

| Country | Ferrovanadium (gross weight) | | Vanadium ore and concentrate (vanadium content) | | Vanadium compounds (gross weight) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Pentoxide (anhydride)[1] | | Other[2] | |
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| Argentina | -- | -- | -- | -- | 2 | 13 | -- | -- |
| Australia | -- | -- | -- | -- | 74 | 108 | (3) | 7 |
| Austria | -- | -- | -- | -- | 120 | 250 | -- | -- |
| Belgium-Luxembourg | 86 | 507 | -- | -- | 751 | 1,219 | -- | -- |
| Brazil | -- | -- | -- | -- | 401 | 666 | 38 | 48 |
| Canada | 318 | 1,572 | -- | -- | 91 | 244 | 84 | 1,168 |
| Chile | -- | -- | -- | -- | 71 | 88 | 58 | 65 |
| Colombia | -- | -- | -- | -- | 3 | 4 | -- | -- |
| Ecuador | -- | -- | -- | -- | (3) | 2 | -- | -- |
| France | -- | -- | -- | -- | -- | -- | 816 | 15,284 |
| Germany, Federal Republic of | 29 | 169 | -- | -- | -- | -- | (3) | 8 |
| Hong Kong | -- | -- | -- | -- | -- | -- | 86 | 147 |
| India | -- | -- | -- | -- | 11 | 19 | -- | -- |
| Indonesia | -- | -- | -- | -- | 77 | 261 | -- | -- |
| Israel | -- | -- | -- | -- | 1 | 216 | -- | -- |
| Italy | -- | -- | -- | -- | 53 | 67 | -- | -- |
| Japan | -- | -- | -- | -- | 291 | 423 | (3) | 2 |
| Kenya | -- | -- | -- | -- | 17 | 28 | -- | -- |
| Korea, Republic of | -- | -- | -- | -- | 55 | 101 | 16 | 19 |
| Malaysia | 3 | 15 | -- | -- | -- | -- | -- | -- |
| Mexico | 29 | 127 | 5 | 9 | 712 | 1,987 | 90 | 257 |
| Netherlands | 38 | 160 | -- | -- | 106 | 226 | -- | -- |
| Pakistan | -- | -- | -- | -- | 6 | 8 | -- | -- |
| Peru | -- | -- | -- | -- | 3 | 3 | 2 | 5 |
| Philippines | 1 | 4 | -- | -- | 10 | 21 | -- | -- |
| Singapore | -- | -- | -- | -- | 18 | 42 | -- | -- |
| South Africa, Republic of | -- | -- | -- | -- | 184 | 237 | (3) | 2 |

See footnotes at end of table.

## Table 7.—U.S. exports of vanadium in 1985, by country —Continued

(Thousand pounds and thousand dollars)

| Country | Ferrovanadium (gross weight) | | Vanadium ore and concentrate (vanadium content) | | Vanadium compounds (gross weight) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Pentoxide (anhydride)[1] | | Other[2] | |
| | Quantity | Value | Quantity | Value | Quantity | Value | Quantity | Value |
| Spain | -- | -- | -- | -- | -- | -- | ([3]) | 3 |
| Sweden | 167 | 997 | -- | -- | -- | -- | ([3]) | 10 |
| Taiwan | -- | -- | -- | -- | 17 | 27 | -- | -- |
| Trinidad and Tobago | 22 | 89 | -- | -- | -- | -- | -- | -- |
| Tunisia | -- | -- | -- | -- | 28 | 36 | -- | -- |
| Venezuela | 221 | 1,151 | -- | -- | ([3]) | 4 | 1 | 8 |
| Total[4] | 908 | 4,791 | 5 | 9 | 3,053 | 6,300 | 643 | 17,082 |

[1] May include catalysts containing vanadium pentoxide.
[2] Excludes vanadates.
[3] Less than 1/2 unit.
[4] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census, adjusted by the Bureau of Mines.

## Table 8.—U.S. imports of ferrovanadium, by country

(Thousand pounds and thousand dollars)

| Country | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Gross weight | Vanadium content | Value | Gross weight | Vanadium content | Value |
| General imports: | | | | | | |
| Austria | 445 | 363 | 2,022 | 461 | 380 | 1,994 |
| Belgium-Luxembourg | 412 | 331 | 1,598 | 487 | 400 | 1,887 |
| Brazil | 1 | 1 | 16 | ([1]) | ([1]) | 5 |
| Canada | 1,136 | 923 | 4,745 | 418 | 339 | 1,775 |
| China | -- | -- | -- | 44 | 36 | 199 |
| France | 99 | 80 | 416 | -- | -- | -- |
| Germany, Federal Republic of | 558 | 444 | 2,077 | 334 | 252 | 1,238 |
| Japan | 114 | 91 | 498 | -- | -- | -- |
| South Africa, Republic of | -- | -- | -- | 168 | 137 | 614 |
| United Kingdom | 156 | 126 | 565 | 40 | 31 | 149 |
| Total[2] | 2,921 | 2,359 | 11,934 | 1,953 | 1,574 | 7,861 |
| Imports for consumption: | | | | | | |
| Austria | 445 | 363 | 2,022 | 461 | 380 | 1,994 |
| Belgium-Luxembourg | 390 | 313 | 1,504 | 509 | 418 | 1,982 |
| Brazil | 1 | 1 | 16 | ([1]) | ([1]) | 5 |
| Canada | 1,136 | 923 | 4,745 | 418 | 339 | 1,775 |
| France | 99 | 80 | 416 | -- | -- | -- |
| Germany, Federal Republic of | 558 | 444 | 2,077 | 334 | 252 | 1,238 |
| Japan | 114 | 91 | 498 | -- | -- | -- |
| South Africa, Republic of | -- | -- | -- | 168 | 137 | 614 |
| United Kingdom | 156 | 126 | 565 | 40 | 31 | 149 |
| Total[2] | 2,899 | 2,341 | 11,839 | 1,931 | 1,557 | 7,757 |

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census, adjusted by the Bureau of Mines.

### Table 9.—U.S. imports of vanadium pentoxide (anhydride), by country

| Country | 1984 Gross weight (pounds) | 1984 Vanadium content (pounds) | 1984 Value | 1985 Gross weight (pounds) | 1985 Vanadium content (pounds) | 1985 Value |
|---|---|---|---|---|---|---|
| General imports: | | | | | | |
| Belgium-Luxembourg[1] | 33,660 | 18,855 | $40,598 | -- | -- | -- |
| Finland | 494,953 | 277,256 | 1,218,749 | -- | -- | -- |
| Germany, Federal Republic of | 2,000 | 1,120 | 8,643 | 35,554 | 19,916 | $169,721 |
| Japan | -- | -- | -- | 1,200 | 672 | 5,829 |
| Netherlands Antilles[2] | -- | -- | -- | 2,641 | 1,479 | 3,960 |
| South Africa, Republic of | -- | -- | -- | 186,285 | 104,351 | 396,683 |
| United Kingdom | 14 | 8 | 1,184 | -- | -- | -- |
| Total | 530,627 | 297,239 | 1,269,124 | 225,680 | 126,418 | 576,193 |
| Imports for consumption: | | | | | | |
| Belgium-Luxembourg[1] | 33,660 | 18,855 | 40,598 | -- | -- | -- |
| Finland | 494,953 | 277,256 | 1,218,749 | -- | -- | -- |
| Germany, Federal Republic of | 2,000 | 1,120 | 8,643 | 35,554 | 19,916 | 169,721 |
| Japan | -- | -- | -- | 1,200 | 672 | 5,829 |
| Netherlands Antilles[2] | -- | -- | -- | 2,641 | 1,479 | 3,960 |
| United Kingdom | 14 | 8 | 1,184 | -- | -- | -- |
| Total | 530,627 | 297,239 | 1,269,124 | 39,395 | 22,067 | 179,510 |

[1] Queried by the Bureau of Mines.
[2] Used pentoxide received for recycling.

Source: Bureau of the Census, adjusted by the Bureau of Mines.

## WORLD REVIEW

Ferrovanadium consumption in the Western World was estimated to be 21,000 tons of contained vanadium in 1985, a level essentially unchanged from that of 1984. The estimates for these 2 years represented a partial recovery from the depressed levels of 1982-83, but were significantly below the record high of 24,000 tons in 1981. This relatively stable situation mirrored raw steel production, its prodominant end use. The International Iron and Steel Institute reported only a 0.6% increase in total raw steel production over that of 1984 for its 30 member countries. During the second half of 1985, monthly raw steel production in Japan and the United States began to decline below the projected seasonal dip, indicating a slowdown in the recovery. Vanadium consumption by producers of oil country tubular goods was abnormally low. The worldwide oil surplus discouraged sales of seamless tubes, such as drill pipe, well casing, and large-diameter line pipe, that contain vanadium to strengthen the steel.

In the Republic of South Africa, at least three companies were either expanding existing vanadium production capacity or planning construction of entirely new extraction and processing facilities. Highveld continued to strengthen its position as the world's largest supplier of vanadium slags and oxides. The commissioning of a second vanadium-bearing pig iron plant at the company's Witbank iron and steel complex in the Transvaal partially offset the permanent closure of Rautaruukki's two mines in Finland and the deterioration of the uranium-vanadium mining industry of the Colorado Plateau. Vanadiferous slag production facilities were also under construction at the Glenbrook steel plant on the North Island of New Zealand. In Canada, large-scale equipment was under development for extracting vanadium from fly ash generated by commercial oil sands plants.

**Brazil.**—The Brazilian ferroalloys industry has been systematically increasing production of ferrovanadium, ferrocolumbium, and other specialty ferroalloys since the worldwide collapse of ferroalloy prices in 1982. Production of ferrovanadium reached a record high of 998 tons gross weight in 1985, almost double the 503 tons (revised) reported for 1984 and more than eight times the 112 tons of 1983.[9] Approximately 70% of the ferrovanadium produced in 1985 came from the aluminothermic reduction plant of Centroligas-Produtos Siderúrgicos Ltda. in the State of São Paulo. Installed capacity in December 1985 totaled 2,877 tons per year, and was divided between Centroligas-Produtos and four other producers: Cia. Paulista de Ferro-Ligas, Eletrometalur S.A. Indústria e Comércio, Polisinter Indústria e Comércio Ltda., and Termoligas Mineração e Metalurgia S.A. Most of the pentoxide feed was being imported from the Federal Republic of Germany and the Republic of South Africa.

Centro de Pesquisa e Desenvolvimento da Bahia has been evaluating the vanadiferous magnetite deposit at Maracas in the State of Bahia. The Maracas ores reportedly contain 1.0% to 2.2% $V_2O_5$.[7]

**Canada.**—Renzy Mines Ltd., a Toronto-based company, was still planning to construct a vanadium extraction plant near Fort McMurray, Alberta. The Canadian plant would use fly ash from the nearby oil-sands operations of Suncor Inc. as feed, and was one of at least three such extraction plants under development in Alberta. The Renzy Mines operation could become the first Canadian facility to produce vanadium commercially from domestic raw materials. The plant would treat 100 tons of syncrude fly ash per day containing about 4.5% $V_2O_5$ and was expected to have an annual output of 1,300 tons of $V_2O_5$. The facility could begin production as early as mid-1987 and would cost between $4 and $5 million. Renzy Mines was also considering the extraction of scandium, gallium, nickel, and molybdenum from the fly ash.[8]

In a related action, Esso Resources Canada Ltd. of Calgary was contemplating a $290 million expansion of its oil-sands operation at Cold Lake on the Saskatchewan border. The existing 240 wells have been producing a total of 19,000 barrels per day of bitumen from a depth of 500 meters. Steam is injected into the wells to reduce the viscosity of the bitumen so that it can be pumped to the surface. The proposed expansion would raise Esso's output to 95,000 barrels per day. To date, no steps have been taken to recover any of the vanadium contained in the Cold Lake bitumen prior to upgrading.[9]

**China.**—China was expanding the iron and steel complexes at Panzhihua near Dukou in Sichuan Province and at Maanshan in Anhui as part of its seventh 5-year plan (1986-90). Construction of new steelmaking facilities and modernization of existing plants have already begun at the two sites and were expected to be completed by 1995. Panzhihua and Maanshan both have their own titaniferous magnetite mines and are major producers of vanadiferous slag. These slags may assay from 13% to 21% $V_2O_5$ but average about 17%.

The Panzhihua complex would have an annual production capacity of 3.1 million tons of pig iron when the new 1,350-cubic-meter blast furnace is completed. The present plant reportedly was producing 1.7 million tons of pig iron annually with its three existing blast furnaces. According to Xinhua, an official Chinese news agency, the Panzhihua deposit contains more than 10 billion tons of ore and accounts for 87% of the country's vanadium reserves. An earlier report stated that the iron mine had only 1.05 billion tons of ore grading 33.2% Fe, 11.6% titanium dioxide ($TiO_2$), and 0.3% $V_2O_5$.

A new 2,500-cubic-meter blast furnace and a new sinter plant would also be installed at Maanshan. Existing plans called for the 30% to 50% iron ore at Maanshan to be blended with Australian ore as feed for the new sinter plant.

**Finland.**—Rautaruukki underwent a major restructuring in 1985, substantially scaling down its mining and prospecting activities while simultaneously expanding its downstream engineering and manufacturing operations. The state-controlled steel conglomerate discontinued all production of $V_2O_5$, giving up roughly 10% of the world vanadium market. Both the Otanmäki and Mustavaara vanadiferous magnetite mines were closed because of unprofitability, leaving only the Rautuvaara copper-iron mine still in operation. In December, Rautaruukki also sold its mineral rights to the Sokli phosphorus deposit at Savukoski to Kemira Oy.

Ore hoisting was halted at the Otanmäki underground mine in May. Otanmäki had been in continuous production since the startup of byproduct vanadium recovery operations in the summer of 1956. Excavation at the Mustavaara surface mine was phased down during November and terminated in December. The two mines produced a total of 4,850 tons of $V_2O_5$, a drop of 20% from the 6,029 tons of 1984. At the beginning of 1985, 468 workers were employed at Otanmäki and 174 at Mustavaara. Most of the mine workers had been receiving retraining and were transferred to the new Otanmäki and Taivalkoski Works, where railcar manufacturing was inaugurated in August. The two former mining centers have begun fabricating freight cars for the timber, mineral fertilizer, and wine industries of Europe and the U.S.S.R.[10]

**France.**—Pechiney, the French state metals group, was in the second year of a major modernization and consolidation program that could affect the vanadium market to a limited degree over the next 5 years. The group's ferroalloy subsidiary, Pechiney Électrometallurgie (formerly Société Française d'Électrometallurgie), began upgrading silicon metal and other bulk ferroalloy operations at its Anglefort plant southwest of Lake Geneva. Pechiney Électrometallurgie continued to produce ferrovanadium by aluminothermic reduction at Chedde in Savoie. A second subsidiary, Métaux Speciaux S.A., was producing catalytic-grade $VOCl_3$ for the Western European rubber industry at nearby Pombliere.

In early April, the group established a 50-50 joint venture between Pechiney Électrometallurgie and the Brandeis Intsel Group for the marketing of both bulk and specialty ferroalloys, including ferrovanadium. Brandeis, a British company acquired by Pechiney in June 1981, reportedly is the third largest ferroalloy trading company of the market economy countries. Brandeis also acts as an agent for Transvaal Alloys Pty. Ltd., a South African producer of $V_2O_5$.

Howmet Turbine Components Corp., the North American subsidiary of Pechiney, initiated a $16.2 million program in May to expand its casting division at Hampton, VA. Howmet was also spending $3 million on a new addition to its New England Aircraft Products plant at Farmington, CT. The company is a major supplier of investment cast components for gas turbine engines, and consumes sizable amounts of ferrovanadium and other vanadium materials.

In 1984, France imported 2,756 tons of $V_2O_5$ and 689 tons of ferrovanadium. Finland supplied 1,455 tons, or 53%, of the pentoxide, while the bulk of the ferrovanadium came from Belgium-Luxembourg and Austria. Part of the pentoxide was used to produce 1,377 tons of ferrovanadium for export.[11]

**India.**—Work continued at the Regional Research Laboratory in Bhubaneswar to develop an economical method for recovering vanadium from the titaniferous magnetite ores of Orissa and Bihar. Metallurgists at the laboratory have built a coal-fired, five-step furnace for evaluating, on a pilot plant scale, different techniques of salt-roasting the magnetite ores. The five-step furnace uses an inexpensive noncoking coal from the Talcher region of Orissa to generate the hot flue gases needed for roasting.

The ore initially used in the Bhubaneswar studies contained 0.89% $V_2O_5$, 15.26% $TiO_2$, and 81.94% $Fe_3O_4$. The ore was ground to minus 200 mesh, pulverized in a ball mill, mixed with sodium chloride, and then pelletized. Both 5% and 10% NaCl pellets, 12 to 18 millimeters in diameter, were evaluated. The pellets were charged from the furnace roof onto the highest step, and moved to successively lower steps while the hot flue gases passed counter-currently to the charge. The steps allowed the pellets to be roasted at different temperatures ranging from 800° to 1,100° C. The roasted pellets were removed from the lowermost step at prescribed time intervals and then leached with water to produce a sodium vanadate solution. The Bhubaneswar investigators were able to recover as much as 90% of the vanadium after 7 to 8 hours of roasting at temperatures of 950° to 1,000° C.[12]

**Japan.**—Demand for ferrovanadium in Japan deteriorated slightly in 1985 despite a 4.6% increase in annual production of structural steel, tool steel, and other specialty steels. The steel industry consumed only 4,451 tons of ferrovanadium, compared with 4,782 tons (revised) in 1984. There were five producers of ferrovanadium in 1985: Nippon Denko Co. Ltd., Taiyo Mining and Industrial Co. Ltd., Awamura Metal Industry Co. Ltd., Japan Metals and Chemicals Co. Ltd., and Nippon Kokan K.K. Together, they produced 3,696 tons of the ferroalloy, a 10% decrease from the 4,115 tons of 1984.[13] The newest producer, Nippon Kokan, has a plant in Toyama Prefecture and has only been making ferrovanadium since 1983.

Because Japan has no vanadium mines and only a limited processing capability for vanadium-bearing ash and spent catalysts, more than four-fifths of the ferrovanadium produced since 1979 has been made from imported $V_2O_5$. Pentoxide imports fell 18% from 5,072 tons gross weight in 1984 to 4,173 tons in 1985. The Republic of South Africa was the principal supplier of pentoxide to Japan and accounted for 86% of the total gross weight. Ferrovanadium imports continued to decline, dropping from 817 tons gross weight in 1983 to 624 tons in 1984 and then to 504 tons in 1985. All of the imported ferrovanadium in the last 2 years has come from either Austria or the European Communities. Japan exported 11 tons of ferrovanadium to North Korea and less than 0.5 ton to New Zealand.[14]

**Netherlands.**—Exxon Corp. spent more than $800 million to modernize its 25-year-old refinery at Rotterdam. The rebuilt refinery was being equipped with a 32,000-barrel-per-day FLEXICOKING unit that would use thermal cracking rather than traditional catalytic cracking to convert inferior heavy feedstocks into high-quality liquid and gaseous fuels. The new process, under development by Exxon for more than

15 years, would produce only a relatively small amount of vanadium and nickel-rich residual coke—roughly 1% of the heavy feedstock—instead of the typical 25% residuum. More than 95% of the vanadium and nickel contaminants in the original feedstock would be concentrated in this coke. The Rotterdam refinery was shut down on June 15, 1985, to permit unimpoded construction and revamping and was supposed to resume operations in mid-1986. The Rotterdam FLEXICOKING facility and a similar unit being installed at Baytown, TX, were expected to become significant sources of low-cost feed material for United States and European vanadium producers.[15]

**Netherlands Antilles.**—Venezuela and the nearby Netherlands Antilles have been a significant source of vanadium-bearing petroleum residues for the United States since World War II. On March 31, Lago Oil & Transport Co. Ltd., an affiliate of Exxon, closed its oil refinery and transshipment storage facilities on the island of Aruba after more than 60 years of operation. The 420,000-barrel-per-day refinery had been receiving the bulk of its vanadiferous heavy crude from Lagoven S.A., a subsidiary of the Venezuelan Government and PDVSA. The refinery has been operating at two-thirds capacity because of weak international oil prices and showed a $50 million loss for 1984. Lago Oil and Exxon tentatively agreed to sell the refinery to the new Government of Aruba for $1.00. On January 1, 1986, Aruba became an autonomous country within the Kingdom of the Netherlands and was no longer part of the Netherlands Antilles.

Shell Petroleum NV also took steps to close its more modern 320,000-barrel-per-day refinery on Curaçao. In August, Shell sold its refinery and the transshipment facility at Bullenbaai to the Government of Curaçao for a token sum of money. In November, the Venezuelan Cabinet approved a proposal that would allow PDVSA's new subsidiary, Isla Refineria, to lease the Curaçao refinery for 5 years at a cost of $11 million per year. PDVSA would supply the refinery with a total of 150,000 barrels per day of light and medium crudes. At yearend, Shell, Curaçao, and the Venezuelan Government were still involved in negotiations aimed at keeping the refinery in operation.[16]

**South Africa, Republic of.**—Highveld produced 63,207 tons gross weight of slag containing about 25% $V_2O_5$ in calendar year 1985.[17] The vanadium slag was a byproduct of iron smelting operations at the company's Witbank integrated steelworks in the Transvaal. Highveld brought its new No. 2 iron plant into operation on July 15 and exceeded the design capacity of the plant's 63-megavolt-ampere submerged arc smelting furnace within 3 months. Fused flake and $NH_4VO_3$ were produced at the company's Vantra facility, which has four rotary kilns and four multiple-hearth roasters. All four of the roasters were in full operation during the second quarter of 1985 because of increased orders. However, two roasters were taken off-line at the end of June when pentoxide sales slackened. Production by the Vantra Div. was estimated to be 4,900 tons of pentoxide. The vanadium-bearing titaniferous magnetite feed for both facilities came from the Mapochs Mine in the Bushveld Complex north of Roossenekal. During the year, the mine shipped 1.67 million tons of lumpy magnetite ore to the steelworks and 0.40 million tons of fines to the Vantra facility. Combined ore shipments were 19% higher than the 1.73-million-ton (revised) total for 1984.[18]

On August 21, Phibro-Salomon Inc., the international investment and commodities trading group, announced that it was withdrawing from all of its remaining businesses in the Republic of South Africa. Some analysts suggested that the withdrawal was prompted by management's concerns about the current sociopolitical situation in the Republic of South Africa, growing pressures in the United States to divest South African stocks, and diminishing returns from bulk ferroalloy sales.[19] The move was significant because of Phibro-Salomon's close financial ties to Anglo American Corp. of South Africa Ltd. The Philipp Brothers Inc. subsidiary of Phibro-Salomon was planning to close its ferroalloys and precious metals trading office in Johannesburg as soon as existing South African contracts expired. Philipp Brothers had been acting in Europe as a marketing agent for a variety of South African materials, including the $V_2O_5$ produced by Highveld. Highveld, the largest vanadium producer within the market economy countries, is a subsidiary of the Anglo American Industrial Corp. A new trading company, Newco, formed by Anglo American Industrial, Barlow Rand Ltd., and three former Philipp Brothers' employees, was given responsibility for marketing Highveld's $V_2O_5$ after January 1986. Newco will be headquartered in Switzerland.

East Rand Consolidated PLC (ERC), a

British finance company with South African mining interests, was in the process of raising $13.5 million to develop a major vanadium mine and processing plant in the eastern portion of the Transvaal.[29] The proposed open pit operation would be on the Kennedy's Vale Farm in the Lydenburg District of the Bushveld Complex and would be managed by Vansa Vanadium S.A. Ltd., a newly formed subsidiary of ERC. The vanadium-bearing titaniferous magnetite ore occurs in plug-like masses that average 1.8% $V_2O_5$, 13.1% $TiO_2$, and 56.7% Fe. These plug-like masses are situated within the mafic layered complex at a position stratigraphically above the platinum-rich Merensky Reef and the underlying chromite horizons.

The principal plug was mined previously by Highveld between 1960 and 1972. During that 12-year period, Highveld removed 2.58 million tons of ore grading 1.98% $V_2O_5$. Subsequent drilling by Vansa has delineated an ore body 340 meters long, 24 meters wide, and at least 100 meters deep within a pyroxenite envelope. The ore body contains an estimated 3.22 million tons of magnetite ore averaging 1.95% $V_2O_5$. An additional 1.5 million tons of ore averaging 0.4% $V_2O_5$ exists in a mineralized zone that extends 13 meters into the hanging wall and 11 meters into the footwall.

The new operation was projected to produce 3,300 tons of 99% $V_2O_5$ fused flake annually from 220,000 tons of ore. At that rate, the mine would have 15 to 20 years of reserves. This production could help offset the drop in world supply created by the permanent closure of Rautaruukki's two mines in Finland and the indefinite shutdown of numerous, but smaller uranium-vanadium mines on the Colorado Plateau. It would cost an estimated $14.4 million to bring the proposed mine into full production by 1988. ERC was also considering mining platinum-group metals from the Merensky Reef and the stratigraphically lower $UG_2$ Reef. The company has already drilled a total of five exploratory holes into the two platiniferous horizons.

### Table 10.—Vanadium: World production, by country[1]

(Short tons of contained vanadium)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Production from ores, concentrates, slags:[2] | | | | | |
| Australia (in vanadium pentoxide product)[3] | 77 | [r]25 | -- | -- | -- |
| Chile[e] [4] | 140 | -- | -- | -- | -- |
| China (in vanadiferous slag product)[e] | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 |
| Finland (in vanadium pentoxide product) | 3,431 | 3,470 | 3,516 | 3,376 | [5]2,716 |
| Norway[e] | 380 | 120 | -- | -- | -- |
| South Africa, Republic of:[6] | | | | | |
| Content of pentoxide and vanadate products[e] | 4,648 | 3,981 | 4,117 | [r]6,633 | 6,520 |
| Content of vanadiferous slag product[e] [7] | 9,260 | 8,930 | 5,620 | [r]7,165 | 8,929 |
| Total | 13,908 | 12,911 | 9,737 | 13,798 | [5]15,449 |
| U.S.S.R.[e] | 10,500 | 10,500 | 10,500 | 10,500 | 10,500 |
| United States (recoverable vanadium) | 5,126 | 4,098 | 2,171 | 1,617 | W |
| Total | 38,562 | [r]36,124 | 30,924 | 34,291 | 33,665 |
| Production from petroleum residues, ashes, spent catalysts: [8] | | | | | |
| Japan (in vanadium pentoxide product) | 687 | 754 | 778 | [e]770 | 840 |
| United States (in vanadium pentoxide and ferrovanadium products) | 1,900 | 1,513 | 893 | 1,701 | 2,695 |
| Total | 2,587 | 2,267 | 1,671 | 2,471 | 3,535 |
| Grand total | 41,149 | [r]38,391 | 32,595 | 36,762 | 37,200 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]In addition to the countries listed, vanadium is also recovered from petroleum residues in the Federal Republic of Germany, the U.S.S.R., and several other European countries, but available information is insufficient to make reliable estimates. Table includes data available through July 8, 1986.

[2]Production in this section is credited to the country that was the origin of the vanadiferous raw material.

[3]Reported output for export.

[4]Based on U.S. imports of vanadium-bearing slag.

[5]Reported figure.

[6]Includes production for Bophuthatswana.

[7]Data on vanadium content of vanadium slag are estimated on the basis of a reported tonnage of vanadium-bearing slag (gross weight) multiplied by an assumed grade of 14.1% vanadium.

[8]Production in this section is credited to the country where the vanadiferous product is extracted; available information is inadequate to permit crediting this output back to the country of origin of the vanadiferous raw material.

## TECHNOLOGY

An evaluation of the iron-vanadium binary phase diagram was published in June by a scientist at Iowa State University.[21] The iron-vanadium binary is a relatively simple system with continuous solid solution at elevated temperatures and an intermediate phase that forms congruently from the high-temperature solid solution near equiatomic stoichiometry. The evaluation work was carried out at the Ames Laboratory as part of an international effort coordinated by the ASM and the National Bureau of Standards that provides industry with assessed phase diagrams of potential interest.

The petroleum industry has been studying the occurrence of vanadium, nickel, and other transition metals in crude oil for several decades. However, downward pressure on oil prices and the increasing amounts of heavy oil being refined have caused research on the subject to be stepped up. Even small amounts (i.e., 5 to 75 parts per million) of vanadium in refinery feedstocks can seriously degrade the activity of the cracking catalysts, resulting in increased gas and coke formation and reduced yields of gasoline. The burning of vanadium-bearing fuel oil at power stations produces corrosive vanadium ash that, if allowed to build up, can damage turbine rotors and refractory furnace linings.

As much as 40% of the vanadium and nickel may be present in the petroleum as metalloporphyrins (nitrogen-metal organocomplexes formed from four pyrrole rings). A significant part of the research on the nature of the metalloporphyrins and other metal complexes in petroleum was to be presented at a symposium sponsored by the American Chemical Society.[22] Because vanadium in the tetravalent state is paramagnetic and frequently occurs as the vanadyl complex cation ($VO^{+2}$) in crude oil and bitumen, electron paramagnetic resonance (EPR) is an effective tool for studying the distribution of vanadium between the metalloporphyrins, nonporphyrin complexes, and associated mineral clays such as montmorillonite and illite. EPR studies at Texas Christian University have confirmed that much of the vanadium in the asphaltene fractions from the Boscan heavy crude of Venezuela and the Circle Cliffs tar sands of Wyoming are in the form of vanadyl etioporphyrin. A joint team of researchers at the University of California at Berkeley and the Chevron Research Co. in neighboring Richmond, CA, have been using electron spin resonance spectroscopy (ESR) to analyze some of the vanadyl nonporphyrin compounds found in heavy crude. Similar ESR studies of vanadyl complexes in asphaltenes and maltenes were being carried out at the Chiyoda Chemical Engineering and Construction Co. Ltd., in Yokohama, Japan.

During the refining of heavy crude, the vanadium fouls the hydrodesulfurization (HDS) catalysts by depositing at the mouths of the particle pores. The nickel, in contrast, is able to penetrate deeper into the particle. Researchers at the Georgia Institute of Technology have been working with the American Cyanamid Co. to develop a process for removing the vanadium and nickel contaminants from the HDS catalysts without removing the active cobalt and molybdenum constituents. One promising rejuvenation method involves pretreating the catalyst with a 5% hydrogen sulfide-helium mixture at 540° C followed by the extraction of the vanadium and nickel with an acidic solution of ferric ion at 100° C.[23]

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# Vermiculite

### By A. C. Meisinger[1]

U.S. production of vermiculite concentrate in 1985 decreased slightly to 314,000 short tons sold and used and increased slightly in value to $32.4 million, compared with 315,000 tons and $31.5 million in 1984. Sales of exfoliated vermiculite from 41 plants in 27 States decreased slightly in quantity to 258,000 tons valued at $47.9 million.

Carolina Vermiculite Inc., Woodruff, SC, began mining and milling vermiculite during the year from deposits in Spartanburg and Laurens Counties, SC.

The United States and the Republic of South Africa continued to be the leading vermiculite producing countries with 93% of the estimated world production of 556,000 tons.

**Domestic Data Coverage.**—Domestic production data for vermiculite are developed by the Bureau of Mines from two separate voluntary surveys, one for domestic mine operations and the other for exfoliation plant operations. Of the four mining operations to which a request was sent, three responded. The one nonrespondent's data were estimated using previous years' production levels adjusted by trends in employment and other guidelines. Of the 43 exfoliating plants to which a request was sent, 41 were active, and 38, or 93%, responded, representing 85% of the total exfoliated vermiculite sold and used shown in table 1. Plant data for the three nonrespondents were estimated using reported previous years' production levels adjusted by trends in employment and other guidelines.

**Table 1.—Salient vermiculite statistics**

(Thousand short tons and thousand dollars unless otherwise specified)

|  | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: |  |  |  |  |  |
| Sold and used by producers: |  |  |  |  |  |
| Concentrate | 320 | 316 | 282 | 315 | 314 |
| Value | $26,200 | $28,500 | $27,200 | $31,500 | $32,400 |
| Average value[1] dollars per ton | $81.88 | $90.19 | $96.45 | $100.00 | $103.18 |
| Exfoliated | 274 | 235 | 224 | 264 | 258 |
| Value | $58,600 | $55,500 | $52,200 | $56,500 | $47,900 |
| Average value[1] dollars per ton | $213.87 | $236.17 | $233.04 | $214.02 | $185.66 |
| Exports to Canada | 31 | 22 | 19 | 22 | [e]23 |
| Imports for consumption | [e]27 | [e]21 | [e]24 | 32 | [e]38 |
| World: Production[2] | 577 | 560 | 490 | [p]545 | [e]556 |

[e]Estimated. [p]Preliminary.

[1] Based on rounded data.

[2] Excludes production by centrally planned economy countries.

## DOMESTIC PRODUCTION

U.S. production of vermiculite concentrate decreased slightly in tonnage to 314,000 tons valued at $32.4 million.

W. R. Grace & Co. continued as the leading domestic producer with operations at Libby, MT, and Enoree, SC. Vermiculite was also mined and processed by Patterson Vermiculite Co. near Enoree, SC, by Carolina Vermiculite, Woodruff, SC, and by Virginia Vermiculite Ltd. in Louisa County, VA. Carolina Vermiculite went on-stream in mid-1985 with processing operations near Woodruff and mines in Spartanburg and Laurens Counties, SC.

Domestic sales of exfoliated vermiculite by 12 producers declined slightly in quantity to 258,000 tons, and 15% in value to $47.9 million. Output came from 41 plants in 27 States, of which 29 plants in 24 States were operated by W. R. Grace.

In descending order of exfoliated vermiculite output sold and used, the principal producing States were California, Ohio, Florida, South Carolina, Texas, New Jersey, and Illinois.

## CONSUMPTION AND USES

Apparent domestic consumption of vermiculite concentrate was 329,000 tons, a sight increase from 325,000 tons (revised) in 1984.

The quantity of exfoliated vermiculite sold and used for both construction aggregate material and agriculture increased slightly; however, insulation uses declined 14% from those of 1984. Other uses in 1985 increased 48% to 4,600 tons.

### Table 2.—Exfoliated vermiculite sold and used in the United States, by end use

(Short tons)

| End use | 1984 | 1985 |
|---|---|---|
| Aggregates: | | |
| Concrete | 51,600 | 52,700 |
| Plaster | 2,700 | 2,500 |
| Premixes[1] | 80,300 | 80,200 |
| Total[2] | [r]134,700 | 135,300 |
| Insulation: | | |
| Loose-fill | 25,900 | 20,500 |
| Block | 38,500 | 35,700 |
| Other[3] | 3,300 | 1,700 |
| Total | 67,700 | 57,900 |
| Agricultural: | | |
| Horticultural | 22,100 | 22,400 |
| Soil conditioning | 4,700 | 8,400 |
| Fertilizer carrier | 31,600 | 29,000 |
| Total | 58,400 | 59,500 |
| Other[4] | 3,100 | 4,600 |
| Grand total[2] | 264,000 | 258,000 |

[r] Revised.

[1] Includes acoustic, fireproofing, and texturizing uses.

[2] Data may not add to totals shown because of independent rounding.

[3] Includes high-temperature and packing insulation and sealants.

[4] Includes various industrial uses not specified.

### Table 3.—Active vermiculite exfoliating plants in the United States in 1985

| Company | County | State |
|---|---|---|
| A-Tops Corp | Beaver | Pennsylvania. |
| Brouk Co | St. Louis | Missouri. |
| W. R. Grace & Co., Construction Products Div | Irondale | Alabama. |
|  | Maricopa | Arizona. |
|  | Pulaski | Arkansas. |
|  | Alameda | California. |
|  | Orange | Do. |
|  | Denver | Colorado. |
|  | Broward | Florida. |
|  | Duval | Do. |
|  | Hillsborough | Do. |
|  | Du Page | Illinois. |
|  | Campbell | Kentucky. |
|  | Orleans | Louisiana. |
|  | Prince Georges | Maryland. |
|  | Hampshire | Massachusetts. |
|  | Wayne | Michigan. |
|  | Hennepin | Minnesota. |
|  | St. Louis | Missouri. |
|  | Douglas | Nebraska. |
|  | Mercer | New Jersey. |
|  | Cayuga | New York. |
|  | Guilford | North Carolina. |
|  | Oklahoma | Oklahoma. |
|  | Multnomah | Oregon. |
|  | Lawrence | Pennsylvania. |
|  | Greenville[1] | South Carolina. |
|  | Davidson | Tennessee. |
|  | Bexar | Texas. |
|  | Dallas | Do. |
| Intermountain Products Inc | Salt Lake | Utah. |
| Koos Inc | Kenosha | Wisconsin. |
| O. M. Scott & Sons | Union | Ohio. |
| Patterson Vermiculite Co | Laurens | South Carolina. |
| Robinson Insulation Co | Cascade | Montana. |
| The Schundler Co | Middlesex | New Jersey. |
| Strong-Lite Products Corp | Jefferson | Arkansas. |
| Strong-Lite Products Corp. of Illinois | De Kalb | Illinois. |
| Verlite Co | Hillsborough | Florida. |
| Vermiculite Products Inc | Harris | Texas. |

[1] 2 plants in the county.

## PRICES

The average value of vermiculite concentrate sold and used by U.S. producers increased slightly to about $103 per ton, f.o.b. plant. The average value of exfoliated vermiculite, f.o.b. plant, declined for the third straight year from $214 per ton to $186 per ton, a 13% decrease.

Engineering and Mining Journal quoted yearend prices for unexfoliated vermiculite as follows, per short ton: Montana and South Carolina, f.o.b. mine, $96 to $143.50; and the Republic of South Africa, c.i.f. Atlantic ports, $90 to $150.

## FOREIGN TRADE

Imports of vermiculite concentrate from the Republic of South Africa were estimated to be 38,000 tons, compared with 32,000 tons (revised) in 1984. Exports to Canada were estimated to be 23,000 tons and represented 7% of total sales.

## WORLD REVIEW

World production was estimated to be 556,000 tons, a slight increase over 1984 production of about 545,000 tons. The United States and the Republic of South Africa, together, accounted for 93% of the total 1985 output. Vermiculite concentrate production in the Republic of South Africa increased 6% to about 203,000 tons, and exports accounted for 86% of production.

### Table 4.—Vermiculite: World production, by country[1]

(Short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Argentina | 3,557 | 3,697 | 4,355 | 4,906 | 4,400 |
| Brazil | 15,771 | 15,497 | 10,888 | 10,094 | 11,000 |
| Egypt | 800 | 309 | 331 | [e]360 | 360 |
| India | 3,995 | 2,280 | 2,658 | 2,153 | 2,200 |
| Japan[e] | 19,000 | 19,000 | 19,000 | 19,000 | 19,000 |
| Kenya | [e]2,900 | 1,715 | [e]1,300 | 961 | 1,100 |
| Mexico | 657 | 575 | 440 | 557 | 550 |
| South Africa, Republic of | 210,101 | 201,327 | 168,691 | 191,536 | [2]202,902 |
| Tanzania | (3) | (3) | (3) | (3) | NA |
| United States (sold and used by producers) | 320,000 | 316,000 | 282,000 | 315,000 | [2]314,000 |
| Total | [r]576,781 | [r]560,400 | 489,663 | 544,567 | 555,512 |

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1] Excludes production by centrally planned economy countries. Table includes data available through July 15, 1986.

[2] Reported figure.

[3] Revised to "Not available." Output is not officially reported and available information is inadequate for formulating reliable estimates of output levels, if any.

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[1] Industry economist, Division of Industrial Minerals.

# Zinc

## By James H. Jolly[1]

World mine and smelter production were at record-high levels, whereas the U.S. zinc producing industry continued to decline. As a result of strikes and mine closures, domestic mine production fell for the fifth straight year, and 1985 was the lowest zinc output year in 77 years. Smelter output also fell owing mainly to the indefinite closure of a primary smelter in Texas early in the year. A primary smelter in Idaho, which had been indefinitely closed since December 1981, was closed permanently in 1985. As a result, U.S. primary zinc smelting capacity was reduced 20% to 404,000 metric tons. The United States accounted for about 3.9% of the world zinc mine output and 4.8% of the world zinc metal production, compared with 5.8% and 6.1%, respectively, in 1980.

World zinc consumption was at an all-time high. The United States was the leading zinc consumer, although zinc consumption declined in 1985. Domestic demand for zinc was met mainly by imports, largely from Canada. Slab zinc imports accounted for about 65% of the apparent slab zinc consumption, and zinc oxide imports cap-

**Table 1.—Salient zinc statistics**

(Metric tons unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| **United States:** | | | | | |
| Production: | | | | | |
| Domestic ores, recoverable content | 312,418 | 303,160 | 275,294 | 252,768 | 226,545 |
| Value thousands | $306,879 | $257,116 | $251,204 | $270,833 | $201,607 |
| Slab zinc: | | | | | |
| From domestic ores | 259,835 | 193,284 | 210,315 | 197,912 | 172,773 |
| From foreign ores | 86,728 | 34,892 | 25,379 | 55,220 | 63,204 |
| From scrap | 50,192 | 74,288 | 69,390 | 78,118 | 75,574 |
| Total | 396,755 | 302,464 | 305,084 | 331,245 | 311,551 |
| Secondary zinc[1] | 290,658 | 210,681 | 279,237 | 320,456 | 289,440 |
| Exports: | | | | | |
| Ores and concentrates (zinc content) | 54,232 | 77,289 | 60,168 | 30,579 | 23,264 |
| Slab zinc | 323 | 341 | 427 | 760 | 1,011 |
| Imports for consumption: | | | | | |
| Ores and concentrates (zinc content) | 245,710 | 66,809 | 63,156 | 86,172 | 90,186 |
| Slab zinc | 612,007 | 456,233 | 617,679 | 639,228 | 610,900 |
| Stocks of slab zinc, Dec. 31: | | | | | |
| Producer and consumer | 126,581 | 111,777 | 112,940 | 118,834 | 91,342 |
| Merchant | 68,773 | 47,397 | 35,199 | 18,792 | 27,163 |
| Government stockpile | 340,581 | 340,578 | 340,577 | 340,577 | 340,577 |
| Consumption: | | | | | |
| Slab zinc: | | | | | |
| Reported | 840,875 | 709,491 | 805,891 | 848,903 | 764,752 |
| Apparent[2] | 938,886 | 794,536 | 933,371 | 980,226 | 940,561 |
| All classes | 1,189,369 | 953,111 | 1,120,548 | 1,214,558 | 1,095,364 |
| Price: High Grade, cents per pound (delivered) | 44.56 | 38.47 | 41.39 | 48.60 | 40.37 |
| **World:** | | | | | |
| Production: | | | | | |
| Mine thousand metric tons | r5,919 | r6,126 | 6,351 | p6,564 | e6,656 |
| Smelter do | r6,081 | r5,866 | 6,201 | p6,463 | e6,567 |
| Price: Prime Western, London, cents per pound | 38.34 | 33.74 | 34.73 | 40.46 | 36.23 |

eEstimated. pPreliminary. rRevised.

[1] Excludes redistilled slab zinc.

[2] Domestic production plus net imports plus/minus stock changes.

tured a record high 22% of the apparent zinc oxide consumption. Zinc prices rose through May, then fell for the rest of the year as demand weakened. At yearend, zinc prices, in constant dollar terms, were among the lowest recorded since the early 1930's.

**Domestic Data Coverage.**—Domestic data for zinc are developed by the Bureau of Mines from seven separate, voluntary surveys of U.S. operations. Typical of these surveys is the annual zinc survey, which, in part, covers the primary and secondary slab zinc producers. Of the 15 slab zinc producers to which the survey request was sent, 12 responded, representing 76% of the total slab zinc production shown for 1985 in tables 1, 7, and 8. Production for the three nonrespondents was estimated using prior year production levels.

**Legislation and Government Programs.**—The National Defense Stockpile goal for zinc was 1,292,739 tons, unchanged since May 1980. The total zinc inventory held by the Government at yearend was 343,202 tons, including 2,625 tons of zinc in the form of brass.

On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. According to the NSC guidelines, zinc would be categorized in tier II, and the goal would be 77,110 tons of zinc metal. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Public Law 96-510), commonly known as the Superfund, expired on September 30, 1985. Various reauthorization bills, such as S. 51, passed by the Senate on September 26, and H.R. 2817, passed by the House of Representatives on December 10, were under consideration by the Congress.

In August, the Environmental Protection Agency (EPA) issued new provisions designed to ensure proper handling of waste generated by about 175,000 businesses, including plants that roll, cast, coat, and draw nonferrous metals. Businesses that produce between 220 and 2,200 pounds of hazardous waste per month were covered. In November, EPA established new regulations covering effluent limits for foundry and die-cast companies in four metal categories, including zinc. Principal pollutants likely to be found in the plant's untreated waste waters were suspended solids, oil and grease, toxic metals, and chemicals. Most of the secondary zinc industry was excluded because the zinc recovery methods did not require process water.

The Occupational Safety and Health Administration promulgated rules in November that required manufacturers and distributors, including recyclers and scrap processors, to collect and provide data sheets on hazardous materials in their products and to label containers they ship out. In May 1986, additional standards were to go into effect requiring training and education of employees in contact with hazardous materials.

## DOMESTIC PRODUCTION

### MINE PRODUCTION

U.S. zinc mine production continued its downtrend for the fifth straight year, resulting in the lowest production year since 1908. Strikes at zinc mines in Tennessee and New York contributed most to the production decline. Tennessee was the principal zinc producing State, followed by Missouri and New York. The leading zinc mine producers were ASARCO Incorporated; St. Joe Minerals Corp., a subsidiary of Fluor Corp.; and Jersey Minière Zinc Co., a subsidiary of the Belgium company Union Minière S.A.

The 25 leading U.S. zinc producing mines accounted for 99% of the zinc mined, with the 10 leading mines accounting for 81%.

In Tennessee, zinc was produced from zinc ore at eight underground mines and from sulfur-copper-zinc ores at underground and open pit operations at Copperhill. Jersey Minière operated the Elmwood and Gordonsville Mines in central Tennessee and was the leading producer in the State in 1985. Zinc output by Asarco, operator of four zinc mines in east Tennessee and usually the leading producer, fell sharply owing to extended strikes during the year. Asarco's Young, Coy, and Immel Mines were struck for 6 months beginning April 1, and the New Market Mine was struck for 4 months beginning May 1. According to Asarco's annual report, the company milled 1.4 million tons of ore from its four mines in 1985, producing 34,020 tons of zinc in concentrate. In 1984, Asarco milled 2.6 million tons of ore, producing 61,050 tons of zinc in concentrate. At yearend 1985, ore reserves at the four mines were estimated by the company to be 6.8 million tons averaging 3.22% zinc.

Inspiration Mines Inc. reopened its Beaver Creek Mine near Jefferson City, TN, in late February following settlement of a 2-month strike. In late November, Inspiration closed down the operation, idling about 120 employees, reportedly because of poor results and declining zinc prices.

Zinc produced in Missouri was a coproduct of lead at seven underground lead mines, all along the Viburnum Trend. Zinc production improved over that of 1984 mainly because the lead-zinc mines in the State were strike-free in 1985. Asarco brought its new West Fork lead-zinc mine on-stream in early September following completion of the underground crusher. Zinc production in concentrate was only 90 tons but was planned to increase to about 2,800 tons or 40% of capacity in 1986. At yearend, the West Fork Mine reportedly had 13.5 million tons of ore reserves averaging 5.5% lead and 1.2% zinc with some copper and silver.

According to company annual reports, AMAX Lead Co. of Missouri and Homestake Mining Co., joint owners of the Buick Mine, mined and milled 2.1 million tons of Buick ore, yielding about 21,870 tons of zinc in concentrate. Although this represented a 52% increase over ore milled in 1984, zinc output was only up about 20% because the average grade of zinc in the ore milled fell 0.4% to 1.4% in 1985. As a result of a revised mining plan, proven and probable ore reserves at the Buick Mine were significantly reduced; however, the average ore grades were up substantially. At yearend, ore reserves were estimated by the operators to be 18.1 million tons grading 8.0% lead and 2.2% zinc compared with 32.7 million tons grading 5.6% lead and 1.4% zinc 1 year earlier.

The Magmont Mine, owned jointly by Cominco American Incorporated, the U.S. subsidiary of Cominco Ltd., and Dresser Industries Inc., was the second leading zinc producing mine in Missouri. According to the Cominco annual report, the company milled 1.04 million tons averaging 7.5% lead and 1.9% zinc and produced 28,100 tons of zinc concentrate containing 16,400 tons of zinc. At yearend, ore reserves at the Magmont Mine reportedly were 6.8 million tons averaging 6.5% lead, 1.1% zinc, and 0.4 troy ounce of silver per ton.

St. Joe operated four of its five zinc producing lead mines in Missouri during the year; the Brushy Creek Mine, closed during a 9-month strike of St. Joe operations in 1984, was not reopened after the strike was settled. According to the company's annual 10K report, St. Joe mined a combined total of 3.2 million tons of ore averaging 5.1% lead and about 0.4% zinc during the fiscal year ending October 31. Zinc production in concentrate was 11,700 tons, compared with 12,250 tons and 19,800 tons, respectively, in fiscal years 1983 and 1984. The zinc concentrates produced in 1985 were sent to St. Joe's zinc refinery in Bartlesville, OK, for processing. Ore reserves at St. Joe's lead mines in Missouri were estimated by the company to be 56.8 million tons averaging 5% lead and 0.5% zinc at the end of the fiscal year.

In New York, St. Joe operated the Balmat and Pierrepont Mines. All ore was milled at the company's Balmat mill, which had an ore milling capacity of about 3,900 tons per day. Production was affected by a strike that began in July and was not settled by yearend. In the latter half of the year, supervisory and nonunion personnel continued both mine and mill production but at a reduced rate. According to the company's 10K report, for the fiscal year ended October 31, St. Joe mined and milled 531,000 tons of ore averaging about 10.7% zinc and produced 53,300 tons of zinc in concentrate. In fiscal year 1984, the company mined 670,000 tons of ore and produced 57,500 tons of zinc in concentrate. At the end of fiscal year 1985, St. Joe estimated that its zinc ore reserves in New York were 3.7 million tons with an average grade of about 13.6% zinc.

In Colorado, zinc production came largely from the Leadville Mine, managed by Asarco but jointly owned by Asarco and Resurrection Mining Co., a Newmont Mining Corp. subsidiary. The State's other significant zinc producer, the Sunnyside gold-silver operation near Silverton, was indefinitely closed in March owing, in part, to financial problems of the mine's owner, Standard Metals Corp. In October, Standard sold the mine to the Canadian firm Echo Bay Mines Ltd., which planned to reopen the mine in the second half of 1986. The Idarado Mining Co. wrote off the asset value of its Idarado lead-zinc-copper-silver-gold mine in Colorado and put aside $1.5 million to eventually permanently close the property. The mine, which is near the Sunnyside Mine, had been closed since 1978.

Asarco reported that it milled 197,000 tons of Leadville ore, slightly more than that of 1984, resulting in a production of 12,060 tons of zinc in concentrate plus 6,080 tons of lead, 344,000 troy ounces of silver, and 17,195 troy ounces of gold. Yearend ore reserves at the Leadville Mine were 748,000 tons averaging 9.14% zinc, 4.35% lead, 0.21% copper, 2.9 ounces of silver per ton, and 0.1 ounce of gold per ton.

In Idaho, Hecla Mining Co., operating the Lucky Friday silver-lead-zinc mine, and Star-Morning Mining Co., operating the Star-Morning Mine under a lease from Hecla, were the only major zinc producers in the State. Minor quantities of zinc were produced at several silver mines. Hecla milled a record high 251,000 tons of ore and produced 3,550 tons of zinc in concentrates at the Lucky Friday Mine in 1985. Ore reserves were up marginally from that of 1984, and at yearend totaled 608,000 tons averaging 1.9% zinc, 16.6% lead, and 18.3 ounces of silver per ton. Star-Morning Mining ceased mining at the Star-Morning Mine late in the year because of poor zinc prices.

Noranda Ltd. and its partners continued underground drilling at the Greens Creek silver-lead-zinc property on Admiralty Island near Juneau, AK. Under the Alaska National Interest Lands Act of 1980, Noranda was given through 1985 to explore the area around its core mining claims; however, a 1-year extension was granted by Congress to do additional exploration because unexplored mineralized areas remained. Ore reserves, based on updated forecasts and mining plans, were reduced in 1985 and at yearend were estimated to be 2.4 million tons averaging 9.05% zinc, 3.50% lead, 0.46% copper, 22.5 ounces of silver per ton, and 0.13 ounce of gold per ton. An operations plan, approved by the U.S. Forest Service, envisioned mine startup in 1988, with an initial zinc production of about 8,000 tons per year, gradually increasing to about 22,000 tons per year.

Two government actions enhanced the development prospects of the huge Red Dog zinc-lead-silver deposit in northwestern Alaska in 1985. The President approved a land swap between the U.S. Park Service and NANA Regional Corp. that provided for a 100-year right-of-way easement through the Cape Krusenstern National Monument to allow construction of a road from the Chukchi Sea to the deposit. In another arrangement, the State agreed to finance construction of the road and port facilities at an estimated cost of $150 million. Plans called for port construction to begin in the summer of 1986, followed by 2 years of road construction beginning in 1987. At yearend, the State and the developers of the Red Dog deposit, Cominco American and NANA, were in the final stages of negotiating a user fee schedule that will reimburse the State for its financing of the road and port facilities. Development of the minesite was expected to begin in 1988 with production expected in 1990. Ore reserves at Red Dog were estimated to be 77 million tons averaging 17.1% zinc, 5% lead, and 2.6 ounces of silver per ton.

The development potential of the Lik lead-zinc deposit, 12 miles north of the Red Dog deposit, was also enhanced by the road and port development plans for northwestern Alaska. Noranda signed a 20-year joint venture agreement in May with GCO Minerals Co., owner of the Lik deposit. Terms of the agreement called for Noranda to spend $25 million for exploration over the next two decades to earn one-half interest in the deposit. The Lik deposit was estimated to contain about 23 million tons of 12% combined lead and zinc.

Centennial Minerals Ltd. and U.S. Minerals Exploration Co. received final approval from the Montana Hard Rock Mining Board to develop an open pit mine at their Montana Tunnels gold-silver-zinc-lead deposit, 35 miles north of Butte. Ore reserves were estimated to be 48 million tons averaging about 0.67% zinc, 0.28% lead, 0.4 ounce of silver per ton, and 0.03 ounce of gold per ton. Initial site preparation was expected to start in March 1986 with production scheduled to begin in May 1987. When fully operational, annual production was projected to be 22,700 tons of zinc, 5,200 tons of lead, 1.7 million ounces of silver, and 106,000 ounces of gold. Late in the year, the Canadian firm Pegasus Gold Inc. acquired Centennial Minerals and its 50% interest in the project, and at yearend, Pegasus was negotiating with U.S. Minerals Exploration to acquire its one-half interest.

Exxon Minerals Co. revised its mining plans at the Crandon deposit in Wisconsin to emphasize zinc production as opposed to simultaneous zinc-copper production. Under the new plan, the massive sulfide ore, which contains most of the zinc, would be mined first, leaving the stringer ore, which is mainly copper, to be mined later. In addition, the company expected to lower its daily production rate to 6,400 tons, down from the 8,300 tons initially planned. State permitting continued to delay development of the property but was progressing. At yearend, the impact of ground water drawdown owing to underground mining and drawdown effects on nearby lakes and streams was the principal concern. If all permits were obtained in 1986, Exxon envisioned production to start in the early 1990's.

### SMELTER AND REFINERY PRODUCTION

Slab zinc was produced at five primary smelters and eight secondary plants in 1985. Production was down slightly from that of 1984 owing mainly to the indefinite closure of Asarco's Corpus Christi, TX, zinc refinery on April 1. The leading producers of primary slab zinc were St. Joe, Jersey Minière, and AMAX, and the leading producers of metal from secondary materials were St. Joe, Huron Valley Steel Corp., and Interamerican Zinc Co.

Asarco closed its 104,000-ton-per-year zinc refinery in Texas owing to poor results caused mainly by low metal prices, high power costs, and to a lesser extent, lack of feed materials. The shutdown of the plant, which had only resumed production in May 1984 after an 18-month suspension of operations, resulted in the layoff of about 275 workers. Metal production for the year totaled 11,400 tons, compared with a production of 28,500 tons in 1984. The closure represented $120 million of the $216 million writeoff the company took against its fourth-quarter 1984 results. As a result of the closing and to maintain other domestic operations requiring zinc metal, Asarco arranged a partial toll contract with Jersey Minière to provide metal in return for zinc concentrates from its Tennessee zinc mines.

St. Joe, owner of zinc refineries at Bartlesville, OK, and Monaca, PA, was the largest domestic producer of slab zinc, accounting for about 40% of U.S. production. The Bartlesville refinery, which was acquired in August 1984, operated near capacity in 1985, utilizing mainly purchased concentrate but also concentrates from St. Joe's lead-zinc mines in Missouri and from Asarco under a tolling arrangement. In fiscal year 1985, St. Joe's zinc refineries produced 147,200 tons of zinc in the form of slab zinc, dust, and oxide.

Bunker Ltd. permanently closed its 103,000-ton-per-year zinc refinery at the Bunker Hill Mine and smelter complex at Kellogg, ID. The complex was closed indefinitely in December 1981. In October, Bunker auctioned off substantial amounts of the complex's machinery, equipment, and metals used for electrolytic processing. Large items, including the zinc plant with or without the buildings and compressor room and electrical equipment, were scheduled to be sold through private negotiations.

Federated Metals Corp., a wholly owned subsidiary of Asarco, closed its zinc dust plant at Sand Springs, OK, in October owing to poor financial results. Federated had previously closed zinc-dust producing plants at Trenton, NJ, and Whiting, IN, in January 1983 for similar reasons.

**Zinc Oxide.**—The raw material sources of domestic zinc oxide production were 35% from ores and concentrates, 36% from slab zinc, and 29% from secondary materials. French-process zinc oxide accounted for about 65% compared with about 64% in 1984. Zinc oxide was produced at 11 plants. The largest producers of zinc oxide were Asarco; The New Jersey Zinc Co. Inc. (NJZI), a subsidiary of Horsehead Industries Inc. (HII); Pacific Smelting Co.; and St. Joe.

Zinc oxide production at Asarco's two plants, at Columbus, OH, and Hillsboro, IL, was 23,360 tons compared with 31,860 tons in 1984. The Columbus plant, which has a capacity to produce 21,000 tons of American-process zinc oxide annually, was written down against fourth-quarter 1984 results and was scheduled to be permanently closed in the second quarter of 1986. With this closure, the NJZI plant at Palmerton, PA, would be the only domestic producer of American-process zinc oxide.

NJZI processed direct-shipping ore from its Sterling, NJ, mine, slab zinc, and waste and scrap materials to produce both American- and French-process zinc oxide at its plant at Palmerton, PA. An NJZI sister company, Horsehead Resource Development Co. (HRD), also a subsidiary of HII, used Waelz-kiln and sintering facilities at the Palmerton plant to produce crude zinc oxide from steelmaking electric arc furnace (EAF) dusts. The crude zinc oxide products, which typically contained about 55% zinc, 6% lead, and some cadmium, were further processed into marketable metal and zinc oxide at the plant or were shipped elsewhere. In 1985, HRD processed about 54,000 tons of EAF dust, which generally contained 20% or higher zinc content; HRD planned to double the tonnage processed in 1986. Standard treatment cost per ton of EAF dust was about $45; an additional cost of $3 to $4 per ton was charged per percent zinc under 20%.

**Zinc Salts.**—Zinc sulfate was produced by 11 companies from secondary materials and concentrate; most was used for agricultural purposes. Zinc chloride was produced entirely from secondary materials by seven companies.

**Byproduct Sulfur.**—Production of sulfur in byproduct sulfuric acid at five primary zinc plants and one zinc oxide plant from zinc sulfide concentrates was 140,700 tons compared with 144,700 tons in 1984. The decrease was due mainly to decreased output at Asarco's zinc refinery in Texas. The estimated value of the sulfuric acid produced at zinc plants was $17.6 million, up $3.1 million from that of 1984.

## CONSUMPTION AND USES

Domestic zinc consumption for most end-use categories fell slightly. The construction industry accounted for about 45% of zinc consumption, followed by transportation, 20%; machinery, 10%; electrical, 10%; and chemical and other industries, 15%. Galvanizing, mainly for sheet and strip, continued to be the principal use of slab zinc, consuming about 47%, followed by zinc-base alloys, 29%; brass and bronze alloys, 10%; rolled zinc, 6%; and other uses, 8%. Of the metal grades consumed, Special High Grade (SHG) accounted for about 55% and was mainly used for the production of zinc-base alloys. The Bureau of the Mint purchased about 28,550 tons of SHG zinc and produced about 10.9 billion pennies, 2.8 billion less than that of 1984. Prime Western (PW) was second in slab zinc consumption and was mainly used for hot-dip galvanizing purposes.

According to the Bureau of the Census, domestic producers' shipments of zinc-base alloy castings were about 312,000 tons, up about 22% from that of 1984. The estimated percentage distribution of zinc die and foundry castings by market sector, based on 1984 data, was as follows: automotive, 32%; builders' hardware, 28%; machinery and household appliances, 18%; electrical components, 15%; and other equipment, 7%.[2]

The average weight of zinc diecastings in the typical 1985 U.S.-built automobile was an estimated 20.2 pounds according to a Zinc Institute Inc. (ZI) study.[3] This represented a 1.5-pound drop from the 1984-model-year average weight and an average decline of 1 pound per year since 1980. The decrease was attributed to continuing weight reduction and downsizing programs, substitution, and improved zinc diecasting methods. Zinc die-cast usage in trucks and vans was not included in the study; however, the typical new truck was estimated to have averaged 15 to 20 pounds of aftermarket or optional equipment zinc diecastings in 1985.

The automobile industry continued to increase the amount of zinc used for corrosion protection per unit vehicle. According to a ZI report,[4] the typical U.S.-built 1985 automobile contained 6.79 pounds of zinc as coating materials in the form of galvanized, electrogalvanized, galvannealed, and zincrometal coated steel. This represented a 0.56-pound gain over the 1984-model average of 6.23 pounds. If zinc-rich paints and a 35% offal factor from coated steel stampings were included, the zinc used for the corrosion protection of a typical domestic-built automobile averaged about 11.4 pounds in 1985 compared with 10.6 pounds in 1984 and 9.7 pounds in 1983. An estimated 42,000 tons of zinc was used for corrosion protection of the 8.2 million U.S.-built automobiles in 1985. The trend toward using less zincrometal and zinc-rich paint and more galvanized and electrogalvanized metal continued. Further increases in zinc and zinc alloy usage for corrosion protection, especially in the form of electrogalvanized steel sheet, were expected. The steel industry was adding about 2.2 million tons of electrogalvanizing capacity, most of which was expected to be on-stream by the end of 1986.

Zinc consumption in copper-base alloys by brass mills, ingot makers, and foundries fell about 19% from that of 1984. According to the Copper Development Association Inc., the brass and bronze industry consumed about 160,000 tons of zinc, the source of which was about equally divided between refined zinc metal and brass and bronze scrap metal.[5] Brass mills accounted for more than 73% of the zinc consumption.

The apparent consumption of zinc oxide was about 177,000 tons, down from 186,000 tons in 1984. Imports were at record-high levels, whereas domestic production and shipments decreased. The rubber industry, which uses zinc oxide as a chemical accelerated and vulcanization activator in rubber processing, continued to be the largest single user of zinc oxide.

## STOCKS

Slab zinc stocks held by domestic producers, consumers, and merchants were less at yearend 1985 than at the start of the year. Weakening prices and demand in the second quarter led to declining stock levels, which recovered some in July and more or less stabilized at that level for the rest of the year. Stocks of slab zinc held in the market economy countries, according to the International Lead and Zinc Study Group (ILZSG), fell about 34,000 tons in 1985, ending the year at 592,000 tons.[6]

Stocks of slab zinc at the London Metal Exchange (LME) ended 1985 at 30,600 tons, up about 1,500 tons from those of 1984. The longstanding good ordinary brand (GOB) zinc contract was phased out in September in preference of the new High Grade (HG) zinc contract. HG zinc accounted for more than 55% of the ending stocks, up from 16% at the start of the year.

Inventories of zinc in ores and concentrates at domestic smelters continuously declined from 66,000 tons in January to 37,000 tons in September, ending the year at 43,500 tons, according to the American Bureau of Metal Statistics Inc. Part of the decline and reduced amount at yearend was attributable to the closing down of Asarco's zinc refinery earlier in the year.

## PRICES

U.S. zinc prices were relatively stable in the first half of 1985 but declined sharply in the second half. U.S. Mint tenders for SHG zinc metal for coin manufacture were major influencing factors in setting zinc-price trends during the year. Low winning bids in the mid-January Mint tender resulted in an almost immediate 2-cent drop to 43 cents per pound in the benchmark U.S. producers' HG zinc price. Higher winning bids in the February tender, coupled with improving zinc market fundamentals, led to a gradual 4-cent-per-pound increase in the benchmark zinc price by the end of April. Market conditions weakened in May, leading to widespread discounting from the producers' price. Lower-than-expected bids in the mid-June Mint tender accelerated a price drop to 41 cents per pound for HG zinc by mid-July. Price weakness continued in the summer months, and in September, surprisingly low Mint tender bids in the 34- to 35-cent-per-pound range for SHG zinc, coupled with continuing deterioration in world zinc market conditions, led to a severe drop to 35 cents per pound in the U.S. producers' HG price. Although this price held to yearend, discounting was widespread. In the first half of 1985, the Metals Week U.S. HG zinc price averaged 43.8 cents per pound, and in the second half, only 37.0 cents per pound.

The 0.5-cent-per-pound premium on the price of PW zinc over the HG zinc price largely disappeared in the domestic market in the latter half of the year. The premium cancellation was attributed to competition mainly from St. Joe, which dropped the PW premium in August 1984.

World zinc prices, which were essentially based on the European producer price (EPP) and LME price, paralleled U.S. price trends in 1985. The EPP, as quoted in Metal Bulletin, increased from $900 per ton at the start of the year to $970 in April before spiraling downward to $670 at the end of the year. The LME prices closely matched the EPP in the early months of 1985, but from May, generally were 3 to 4 cents lower. The collapse of world prices in the latter half of the year was attributed mainly to weakening demand and perceived surpluses of concentrates and metal. Exacerbating the price decline was a widely held perception through most of 1985 that China was reducing its zinc imports below those of 1984; the fact that China purchased about 268,000 tons of slab zinc, 38,000 more than in 1984, was not generally known until late in the year. Despite the price decreases, most Western European and other world zinc producers continued smelter production at high operating rates, in part because concentrates were readily available at favorable treatment-charge rates and because of advantages accruing from currency differences with the U.S. dollar. At yearend, several Western European zinc producers were considering plans to switch from the volatile U.S. dollar-base pricing system to a multicurrency system to reduce unpredictable swings in zinc values generated by currency fluctuations.[7]

American- and French-process lead-free zinc oxide prices at the beginning of the year were quoted in Metals Week at 52 to 54.5 cents and 53.5 to 56.0 cents per pound, respectively. In September, the zinc oxide prices for each fell 3 cents, and in December, prices were adjusted downward, ending the year at 40 to 51 cents per pound for American-process zinc oxide and 41.5 to 53 cents for French-process zinc oxide. Photoconductive grades of zinc oxide were generally priced 2 to 3 cents higher than French-process zinc oxide throughout the year.

The price quoted in Chemical Marketing Reporter (CMR) for zinc sulfate, granular monohydrate industrial grade, 36% zinc in bags in carload lots, ranged from $26.50 to $29.00 per 100 pounds. Agricultural zinc sulfate in bulk was quoted at $20.00 per 100 pounds. Technical-grade zinc chloride, 50% solution, in tanks, was quoted by CMR at $18.40 per 100 pounds until September and $20.20 thereafter. Standard pigment-grade zinc dust, types 1 and 2 in drums, was quoted by CMR at 59 to 67 cents per pound during the year.

## FOREIGN TRADE

U.S. slab zinc imports were about 28,000 tons less than the record-high quantity imported in 1984. Imports from Canada were at record-high levels in terms of tonnage and percentage of U.S. imports. Canada accounted for about 63% of imports compared with an average import level of 54% in the 1980-84 period. The record-high import levels from Canada were, in part, attributed to intercontinental trades to reduce transportation costs. The second leading import source for slab zinc was Mexico, accounting for slightly less than 9%. Zinc oxide imports exceeded 1984's record-high level and captured about 22% of the domestic consumption, up from 20% in 1984.

Despite the closing of Asarco's primary zinc refinery in Texas early in the year, imports of concentrates continued at relatively high levels because of substantial reductions in domestic output. Exports of concentrates fell to their lowest level since 1979 owing mainly to reduced production at exporting mines.

Waste and scrap exports reached record-high levels in 1985; Taiwan was the principal importer, accounting for about 45% of the waste and scrap exported.

**Table 2.—U.S. import duties for zinc materials, January 1, 1985**

| Item | TSUS No. | Most favored nation (MFN) |  | Non-MFN |
|---|---|---|---|---|
|  |  | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Zinc oxide, dry | 473.76 | 0.4% ad valorem | Free | 5.5% ad valorem. |
| Ores and concentrates[1] | 602.20 | 0.39 cent per pound on zinc content. | 0.3 cent per pound on zinc content. | 1.67 cents per pound on zinc content. |
| Fume | 603.50 | do | do | Do. |
| Unwrought, other than alloys | 626.02 | 1.6% ad valorem | 1.5% ad valorem | 1.75 cents per pound. |
| Alloys | 626.04 | 19.0% ad valorem | 19.0% ad valorem | 45.0% ad valorem. |
| Waste and scrap[1] | 626.10 | 2.9% ad valorem | 2.1% ad valorem | 11.0% ad valorem. |

[1] Duty on zinc ores, concentrates, and zinc-bearing materials was suspended until Dec. 31, 1989, as provided by Public Law 98-573.

## WORLD REVIEW

World consumption of zinc metal was an estimated record-high 6.7 million tons in 1985, up slightly over the record consumption posted in 1984. In the market economy countries, zinc metal consumption was about 4.7 million tons, about the same as that of 1984. Consumption decreases in the United States and Western Europe were offset by increases in some of the newly industrialized countries, most notably Brazil. The Western European countries, the United States, and Japan accounted for slightly more than one-half of world consumption.

Both mine and smelter production were also at record-high levels in 1985. World mine output was about 6.7 million tons, up about 0.1 million tons over the 1984 record-high output. Australia, China, North Korea, Peru, and Thailand mined more zinc, whereas Canada, Mexico, and the United States, because of strikes and/or production cutbacks, mined less. Canada continued to be the principal world producer and, together with Australia, Peru, and the U.S.S.R., accounted for about one-half of world output. Smelter production was about 6.6 million tons, up about 0.1 million tons over the record-high production of 1984. Most countries produced at 1984 levels; India, Italy, North Korea, and Thailand increased production, readily offsetting slight production decreases in Japan, the United States, and some Western European countries. Canada, Japan, and the U.S.S.R. produced more than one-third of world smelter output of zinc.

World mine capacity increased to about 8.0 million tons, up about 0.13 million tons from that of 1984 (revised). New mine openings in Canada, Australia, Peru, and Colombia accounted for most of the increase. World primary smelter capacity also was up about 0.1 million tons to 7.9 million tons owing mainly to the opening of a new smelter in Italy.

The world supply-demand position was more balanced than generally anticipated. Metal stock levels in the market economy countries fell for the third straight year, and at yearend, represented the equivalent of about 1 month of world consumption. Despite an apparent balanced world supply-demand situation coupled with slight reductions in world metal stocks, prices declined sharply in the second half of 1985.

ILZSG, at its October meeting, forecast that zinc consumption in the market economy countries would be about 100,000 tons higher in 1986 than in 1985. Forecasts of zinc mine output and zinc metal production showed similar gains.

**Argentina.**—Cía. Minera Aguílar S.A. (CMASA), a St. Joe subsidiary, operated its Aguílar Mine and mill near capacity in the fiscal year ending October 31, and accounted for virtually all of Argentina's primary zinc output. The company produced 31,670 tons of zinc in concentrates in the fiscal year in milling 577,000 tons of ore containing 6.2% zinc, 5.3% lead, and 3.5 ounces of silver per ton. The zinc concentrates were utilized for the production of slab zinc at an electrolytic zinc refinery operated by Cía. Sulfacid S.A.C.I.Y.F. in which CMASA owns a 50% interest. At the end of the fiscal year, the ore reserves at the Aguílar Mine were estimated to be 4.8 million tons with an average grade of 7.1% zinc, 5.7% lead, and 4.0 ounces of silver per ton.

**Australia.**—Australia was the world's third largest mine producer of zinc. Production was up substantially from that of 1984 owing to the return of normal production levels at major mines at Broken Hill, New South Wales, and Tasmania, together with increases at the Elura Mine. One new zinc mine came on-stream in the latter part of the year and the Beltana zinc-lead mine in South Australia, which closed in 1976, was reopened. Production at the Teutonic Bore Mine in Western Australia ceased at yearend because of depletion of ore reserves. Expansions at a number of mines were scheduled for completion in 1986, adding about 20,000 tons to the country's zinc production capacity. Intensive exploration and evaluation of various prospects continued.

The Woodcutters open pit mine near Darwin in the Northern Territory came on-stream late in the year. At capacity, the mine, which is owned by Nicron Resources Ltd. (75%), Lachlan Resources NL (16%), and Petrocarb Exploration NL (10%), was expected to have an annual output of 23,000 tons of zinc, 11,000 tons of lead, and 600,000 ounces of silver in concentrates. Ore reserves were estimated to be 1.1 million tons averaging 14% zinc, 7.7% lead, and 5.7 ounces of silver per ton.

In the fiscal year ending June 30, MIM Holdings Ltd. produced at its Mount Isa Mine in Queensland a record high 202,000 tons of zinc in concentrate in treating about 4.3 million tons of ore grading 6.6% zinc, 5.4% lead, and 5.6 ounces of silver per ton. Zinc-lead-silver ore reserves at yearend 1985 at the Mount Isa Mine were about 49 million tons averaging 6.8% zinc, 5.83% lead, and 7.5 ounces of silver per ton. MIM was developing the Hilton silver-zinc-lead deposit, about 12 miles north of Mount Isa, as a second source of feed for the Mount Isa concentrator because production tonnages from the Mount Isa Mine were expected to start declining after 1990. Plans at Hilton initially called for ore production of about 35,000 tons in fiscal year 1986, increasing gradually to 2.5 million tons by the middle 1990's.[8] The Hilton deposit, which consists of seven stratabound silver-lead-zinc ore bodies in the same geological formations as the Mount Isa deposits, contained an estimated in situ ore reserve of about 72 million tons that averages 10.35% zinc, 6.52% lead, and 3.7 ounces of silver per ton.

The Woodlawn open pit mine in New South Wales became a wholly owned subsidiary of Australian Mining & Smelting Ltd. when they acquired St. Joe International Corp.'s one-third interest. Ore reserves in the pit were expected to be depleted by early 1987; however, an evaluation of mining lower extensions of the ore body by underground methods was under way.

Aberfoyle Ltd. was converting a tin treatment facility in northwest Tasmania to a pilot-scale plant for trial milling of bulk underground ore samples from its Hellyer zinc-lead-silver deposit, just north of the Que River Mine. The estimated in situ ore reserves at Hellyer totaled about 15 million tons averaging 13% zinc, 7% lead, 0.4% copper, 5.0 ounces of silver per ton, and 0.7 ounce of gold per ton. A further 4 million tons of inferred ore reserves was added by exploration activities in 1985. A decision on whether or not to develop the deposit was expected in 1987.

In August, Pancontinental Mining Ltd. acquired MIM's interest in the Lady Loretta zinc-lead-silver deposit in northern Queensland, and later the remaining one-half of the joint venture from Elf Aquitaine Triako Mines Ltd. Late in the year, Pancontinental sold a 49% interest to the Finnish company Outokumpu Oy. Underground exploration was expected to be completed in 1986. Reserves were estimated at 9 million tons grading 14.8% zinc, 6.5% lead, and 3.0 ounces of silver per ton.

**Canada.**—Canada continued to be the world leader in zinc mine production, accounting for more than 18% of world output. Brunswick Mining and Smelting Corp. Ltd.'s (BMS) No. 12 Mine in New Brunswick had the largest zinc production, followed by Kidd Creek Mines Ltd.'s Kidd Creek Mine at Timmins, Ontario, and Cominco Ltd.'s Pine Point and Polaris Mines in the Northwest Territories and the Sullivan Mine in British Columbia. These five mines accounted for two-thirds of Canadian zinc production. About 17 other mine-mill operations accounted for the remaining output. Three new mines, the largest of which was Westmin Resources Ltd.'s H. W. Mine in British Columbia, opened, and two mines closed in 1985. As part of the Government privatization program, the Government-owned Canada Development Corp. sold most of its interest in Kidd Creek Mines to Falconbridge Ltd. in December. Kidd Creek Mines produced about 220,000 tons of zinc in concentrate in 1985.

Canada, the third leading world producer of refined zinc, produced a record high 692,000 tons, up marginally from the record production set in 1984. The four primary smelters operated about 99% of rated combined annual capacity. Owing to weak zinc markets in the second half of the year, several Canadian zinc mine and smelter producers reduced production late in the year or were planning production cutbacks in early 1986.

Curragh Resources Corp. bought most of the assets of the Cyprus Anvil Mining Corp. from Dome Petroleum Ltd. and Trans Canada Pipelines Ltd. in June. The assets purchased included the large Faro lead-zinc-silver open pit mine and several nearby zinc-lead deposits in the Yukon Territory and a 50% interest in the undeveloped Cirque zinc deposit in British Columbia. Curragh, aided by a complex financial plan involving loan credit lines guaranteed by the Yukon and Federal governments, government maintenance of an all-weather road to Skagway, AK, for shipments of concentrates, and incentives provided under the Yukon Mineral Recovery Program, planned to reopen the Faro Mine by the middle of 1986. The Faro Mine, which closed in 1982 for economic reasons, produced 107,000 tons of zinc in milling 2.75 million tons of ore in 1981, its last full year of operation. Curragh was planning to attain a full ore production rate of about 4 million tons by 1987. A mine life of about 7 years was expected. Boliden AB of Sweden contracted to be the general sales agent for Faro's production and also acquired a 10%

interest in the mine in 1985. At yearend, Boliden had reportedly located buyers for the 90,000 tons of zinc concentrates and 40,000 tons of lead concentrates expected to be produced in 1986. At the end of 1984, estimated ore reserves at the Faro open pit were 18.5 million tons grading 5.1% zinc and 3.5% lead with 1.3 ounces of silver per ton.

BMS, 64% owned by Noranda, milled 3.3 million tons of ore at its No. 12 Mine in New Brunswick, down from 3.6 million tons milled in 1984 mainly because of production cutbacks late in the year. Zinc production in zinc and bulk concentrates was down about 21,000 tons from that of 1984, but totaled 237,500 tons or about 20% of Canadian output in 1985. Diamond drilling proved up more ore than was mined out during the year, and at yearend, BMS ore reserves were up 3 million tons to 83 million tons grading 9.15% zinc, 3.73% lead, 0.31% copper, and 3.1 ounces of silver per ton. An additional 21.7 million tons of similar grade, probable ore was also indicated.

Pine Point Mines Ltd., 51% owned by Cominco Ltd., produced about 161,400 tons of zinc in 272,600 tons of concentrate at the Pine Point Mine. The company milled 2.14 million tons of ore, about the same as in 1984. Because of high operating costs, mainly due to increased strip ratios and mine dewatering costs, Pine Point Mines revised its production plans for 1986 and 1987 to maximize and increase production rates and lower costs. As a result of the revised plan, the life of the mine, shortened to about 6 years, was not expected to extend much beyond the opening of Cominco American's Red Dog Mine in Alaska. Also, ore reserves were revised downward about 6 million tons to 14.5 million tons averaging 6.0% zinc and 2.7% lead at yearend. Cominco Ltd. milled a record high 939,000 tons of ore grading 13.1% zinc and 3.5% lead at its Polaris Mine on Little Cornwallis Island, Northwest Territories, in 1985, yielding 117,900 tons of zinc in 190,700 tons of zinc concentrate, and 29,900 tons of lead in 39,300 tons of lead concentrate. Production of zinc and lead, respectively, were 10% and 7% higher than that of 1984. At yearend, ore reserves were 19 million tons averaging 14.3% zinc and 3.8% lead. Concentrate production from the Polaris Mine was shipped to Western European smelters during a 12-week period at the end of the Arctic summer when the sea was open for navigation.

The Sullivan Mine at Kimberley, British Columbia, continued to be the principal supplier of zinc and lead concentrates to Cominco Ltd.'s Trail smelter. The amount of ore milled and production of zinc and lead concentrates was below that of the record highs set in 1984 because of a decision at midyear to reduce output mainly because of weak metal prices. In 1985, 2.2 million tons of ore was milled yielding 76,000 tons of zinc in 154,800 tons of zinc concentrate and 94,400 tons of lead and 251,400 ounces of silver in 152,000 tons of lead concentrate. At yearend, ore reserves at the Sullivan Mine were 32.7 million tons averaging 6.3% zinc, 4.3% lead, and 1.1 ounces of silver per ton.

Falconbridge suspended development work in November on its Winston Lake zinc property in Ontario mainly because of deteriorating zinc prices and poor near-term outlook for zinc concentrate sales. The company had announced in September that it planned to bring the deposit into production by late 1986 at an annual production rate of 50,000 tons of zinc in concentrate. Ore reserves at the deposit were estimated at 2.2 million tons grading 18% zinc, 1.1% copper, 1.0 ounce of silver per ton, and 0.004 ounce of gold per ton.

**China.**—China National Nonferrous Metals Import-Export Corp. signed agreements with several Japanese companies to have a new 60,000-ton-per-year vertical retort zinc smelter built at Huladao in Liaoning Province. The plant, which will replace an existing vertical and horizontal retort smelter of similar capacity, was expected to be onstream in 1987.

**Greenland.**—Greenex A/S, a wholly owned subsidiary of Vestgron Mines Ltd., produced 70,300 tons of zinc in concentrate at the Black Angel zinc-lead-silver mine at Maarmorilik, compared with 71,300 tons in 1984. Although the amount of ore milled was up 53,000 tons to 728,000 tons in 1985, the grade of ore milled dropped to 9.6% zinc from 11.0% zinc in 1984. The ore reserves at the Black Angel Mine totaled only 1.4 million tons grading 9.7% zinc, 3.0% lead, and 0.9 ounce of silver per ton at yearend. Because of extremely depressed prices for zinc and lead in the second half of 1985 and its diminished ore reserve position, Greenex was considering whether or not to permanently close the mine. Late in the year, Greenex reached an agreement with its bankers and the Governments of Greenland and Denmark that would permit operations to continue at least until June 1, 1986. Because of the mine's uncertain future, Cominco Ltd., which owns 62.5% of Vestgron, wrote off its $14 million investment in that company in 1985.

**Honduras.**—Rosario Resources Corp., a wholly owned subsidiary of AMAX, continued its program to increase ore production levels at the El Mochito zinc-lead-silver mine to 2,300 tons per day by 1987. As part of an effort to lower production costs, the work force was reduced from 1,500 to 1,200 by the end of the year. Zinc output in concentrates was 44,000 tons in 1985, compared with 41,500 tons in 1984 and 38,000 tons in 1983. A 20% increase in zinc production was expected in 1986. Concentrates were sold to smelters in Japan, Western Europe, and the United States. At yearend, estimated ore reserves at the El Mochito Mine were 4.8 million tons grading 9.0% zinc, 4.6% lead, 0.54% copper, 4.0 ounces of silver per ton, and 0.002 ounce of gold per ton.

**Korea, Republic of.**—Planned expansions at the country's two zinc refineries continued. The Korea Zinc Co. Ltd. was doubling the annual capacity of its Onsan zinc refinery to 150,000 tons. Construction was expected to be completed by the end of 1986. Most of the feed for the Onsan refinery was expected to be imported mainly from Australia. In October 1985, Young Poong Corp. completed a 15,000-ton-per-year expansion of its Seakpho electrolytic zinc refinery, raising the annual capacity to 50,000 tons. Young Poong planned to provide all of the refinery's zinc concentrate feed from the company's nearby mines at Yeonhwa No. 1 and No. 2. In 1985, the company's mines at Yeonhwa produced about 72,000 tons of zinc or about 78% of the domestic production. The ore deposits at Yeonhwa No. 1 consisted of 7 lead-zinc bodies of chimney type and 10 smaller ones of vein type, all occurring in limestone. Reserves were estimated at over 1.5 million tons averaging 0.93% lead and 3.12% zinc. At Yeonhwa No. 2, 10 kilometers northeast of No. 1, the ore bodies occurred typically in moderately dipping limestone and slate beds, associated with intrusive sills and dykes of quartz monzonite porphyry. The estimated ore reserves at Yeonhwa No. 2 were 1.4 million tons grading 0.34% lead, 3.76% zinc, and 0.06% copper. An additional 10 million tons of ore containing 9.3% combined lead and zinc and about 3 ounces of silver per ton was indicated in several newly discovered nearby deposits. Young Poong planned to invest about $6.8 million for development by 1988.

**Mexico.**—Mine production fell in 1985 owing mainly to significant decreases in mine output at mines operated by México Desarrollo Industrial Minero S.A. (MEDIMSA) and Industrias Penoles S.A. de C.V. MEDIMSA's zinc output was about 59,000 tons in 1985, down about 11,000 tons from that of 1984, despite increased zinc production at the San Martin Mine, whose capacity was tripled in 1984. MEDIMSA completed the expansion program at its Charcas zinc-lead-silver mine in San Luis Potosí State in December. Mine and mill capacity was increased from 1,250 tons per day to 3,450 tons and was expected to result in a zinc production increase of 18,000 tons to 33,000 tons in 1986. MEDIMSA's Rosario lead-zinc-copper-silver mine in Sinaloa State was almost completed in 1985. Production at a rate of 550 tons per day was scheduled to start in March 1986. An annual output of about 6,000 tons of lead and 3,000 tons of zinc was planned.

**South Africa, Republic of.**—Shell South Africa (Pty.) Ltd. began open pit development at its lead-zinc deposit at Pering in northern Cape Province late in the year. Shell planned to have the mine in production by September 1986, producing at an annual rate of 33,000 tons of zinc contained in 60,000 tons of concentrate. Also to be produced annually was about 9,000 tons of lead concentrate containing 4,000 tons of lead. The zinc concentrates were scheduled to be processed at the Springs, Transvaal, zinc refinery owned by the Zinc Corp. of South Africa Ltd. Established geological reserves totaled 18.4 million tons averaging 3.61% zinc and 0.64% lead. A mine life of about 17 years was expected.

Prieska Copper Mines (Pty.) Ltd., which had intended to permanently close its Prieska copper-zinc mine by the end of 1985, planned to continue operations for an additional year as sufficient exploitable ore was found to enable mining to continue.

## TECHNOLOGY

The Bureau of Mines devised a technique to recover a zinc-lead concentrate from geothermal brines produced in the Imperial Valley of California.[9] It was estimated that up to 90,000 tons of zinc per year could be extracted from these brines if the geothermal resources were developed to produce 1,600 megawatts of power. More than 99% of the zinc and lead were precipitated by treating the brine with hydrogen sulfide and controlling the pH with lime. A flowsheet for metal recovery was proposed.

The Bureau carried out studies to determine the feasibility of chlorine-oxygen leaching for treating complex low-grade zinc sulfide concentrates that are generally unacceptable as feed for conventional roast-leach-electrowin plants because of the low zinc and high iron contents.[10] A process using the Bureau's chlorine-oxygen leaching technique was expected to result in extraction of about 95% of the zinc in the form of purified crystalline zinc chloride, which could be fed into a molten-salt bath and electrolized to produce zinc metal and chlorine for recycle.

The Bureau conducted research to separate fluorine from byproduct zinc concentrates obtained from fluorspar production in an effort to make the concentrate acceptable to zinc producers,[11] devised a method to recover zinc and other metals from copper converter flue dust,[12] developed technology to use flue dust containing zinc as a source of zinc for electrogalvanizing,[13] and evaluated waste-derived electrogalvanized zinc coatings on wire.[14]

EAF steelmaking dusts, listed as hazardous waste by the EPA mainly because of leachable lead, cadmium, and chromium, continued to be a major problem for the steel industry as disposal costs ranged up to $200 per ton. In 1985, an estimated 450,000 tons of EAF dusts, all of which contained zinc, was generated in the United States. About 10% was utilized as a constituent in fertilizers, 15% was processed to recover zinc, and 75% was disposed of in hazardous landfills. By August 1988, an EPA ban on land disposal of hazardous EAF dust was scheduled, providing suitable treatment technology was available. Studies completed in 1985 by the Center for Metals Production[15] and the Bureau of Mines[16] discussed options available for EAF dust treatment and disposal. The studies considered four basic options: chemically stabilize the dust so it could be landfilled as nonhazardous waste; incorporate or mix with another material so the resultant product could be listed as nonhazardous; recycle directly back into the electric arc furnace to upgrade the zinc content of the dust to produce a salable or processable smelter-feed product; and establish regional processing plants near EAF steelmaking centers to recover zinc, lead, and cadmium and render the residue nonhazardous. Depending on the situation, each of the options were considered likely to be employed in the future. The studies indicated that most zinc recovery methods will require the zinc content in the EAF dust to be higher than 20%.

An upgraded dust product containing more than 50% zinc was considered a salable feed material for most nonelectrolytic zinc smelters. In 1985, a number of plants around the world recovered zinc from steelmaking dusts. In Sweden, a plasma arc reactor capable of processing 70,000 tons of dust per year came on-stream. Zinc metal and nontoxic residue were produced. Plants to process steelmaking dusts were under construction in both France and Spain. The French plant, expected on-stream in early 1986, was designed to process 12,000 tons of dust per month. Lead would be recovered by precipitation and zinc by electrolysis. The Spanish plant, which will employ a Waelz-kiln process, was expected to produce metal oxide briquets suitable as feed for plants using the Imperial Smelting Process. An annual production of about 14,000 tons of lead and zinc contained in briquets from the processing of 70,000 tons of dust was expected to begin in 1987.

A new technique, the Zincquench process, for producing Galfan-coated, dual-phase and related high-strength, deep-drawing steels at lower costs and with improved properties mainly for automotive uses was described.[17] The process consisted of continuous annealing followed by a drastic quench in a 95% zinc-5% aluminum plus some mischmetal alloy bath, followed by an overaging treatment. The new process reportedly avoided some of the complexities of hot-dip galvanizing and provided greater ductibility and corrosion performance than can be attained with electrolytic coating.

A comprehensive coverage of zinc-related investigations and an extensive review of current world literature on zinc extraction, alloys, uses, products, and research was published in quarterly issues of Zinc Abstracts issued by the Zinc Development Association, London, England.[18] The International Lead Zinc Research Organization, a research organization sponsored by private companies, carried out technical research and market development activities mainly related to galvanizing and diecasting alloys and technology.[19]

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[1] Physical scientist, Division of Nonferrous Metals.

[2] Zinc Institute. U.S. Market for Zinc Die Castings 1980-1984. 1984, 10 pp.

[3] ———. U.S. Automotive Market for Zinc Die Castings 1983-1985. 1985, 2 pp.

[4] ———. U.S. Automotive Market for Zinc Coatings 1983-1985. 1985, 3 pp.

[5] Copper Development Association Inc. Annual Data 1986, Copper Supply & Consumption 1965-1985. 1985, 20 pp.

[6] International Lead and Zinc Study Group. Lead and Zinc Statistics. V. 26, No. 6, June 1986, p. 40.

[7] Metals Week. MG May Switch From US-Dollar-Based Pricing. V. 56, No. 50, Dec. 23, 1985, p. 1.

[8] Mining Magazine (London). Mount Isa Mine and the Hilton Project. V. 37, No. 11, Nov. 1985, pp. 421-433.

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[11] Prater, R. B., Jr., V. R. Miller, and E. R. Cole, Jr. Defluorination of Byproduct Zinc Concentrate. BuMines RI 8957, 1985, 13 pp.

[12] Palumbo, F. J., R. L. Marsh, and R. C. Gabler, Jr. Recovery of Metal Values From Copper Converter Flue Dusts. BuMines RI 8995, 1985, 10 pp.

[13] Dattilo, M., E. R. Cole, Jr., and T. J. O'Keefe. Recycling of Zinc Waste for Electrogalvanizing. Conserv. and Recycling, v. 8, Nos. 3-4, 1985, pp. 399-409.

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[15] Mac Rae, D. R. Electric Arc Furnace Dust—Disposal, Recycle and Recovery. Center for Metals Production, No. 85-2, May 1985, 91 pp.

[16] Morris, A. E., E. R. Cole, Jr., L. A. Neumeier, and T. J. O'Keefe. Treatment Options for Carbon Steel Electric Arc Furnace Dust. Paper in Proceedings of 43d Electric Furnace Conf. Iron and Steel Soc. of AIME, Atlanta, GA, 1985, pp. 167-182.

[17] Radtke, S. F. Promising New Zn-Al Alloy Quench Coating Process for Steel Undergoing Production Trials. Ind. Heat., No. 9, Sept. 1985, pp. 21-24.

[18] Zinc Development Association. Zinc Abstracts. V. 43, Nos. 1-4, 1985, 466 pp.

[19] International Lead Zinc Research Organization. ILZRO Annual Review 1985. 13 pp.

### Table 3.—Mine production of recoverable zinc in the United States, by month

(Metric tons)

| Month | 1984 | 1985 |
|---|---|---|
| January | 23,081 | 20,500 |
| February | 24,804 | 22,722 |
| March | 26,627 | 24,527 |
| April | 21,607 | 18,552 |
| May | 23,294 | 19,694 |
| June | 19,749 | 19,366 |
| July | 20,528 | 14,459 |
| August | 16,751 | 14,781 |
| September | 14,927 | 15,458 |
| October | 21,260 | 19,926 |
| November | 21,169 | 16,958 |
| December | 19,021 | 19,602 |
| Total | 252,768 | 226,545 |

### Table 4.—Mine production of recoverable zinc in the United States, by State

(Metric tons)

| State | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Arizona | 138 | -- | -- | -- | -- |
| California | W | -- | -- | -- | -- |
| Colorado | W | W | W | W | W |
| Idaho | W | W | W | W | W |
| Illinois | W | W | W | W | W |
| Kentucky | W | W | W | W | W |
| Missouri | 52,904 | 63,680 | 57,044 | 45,458 | 49,340 |
| Montana | 25 | W | -- | -- | -- |
| Nevada | W | -- | -- | -- | -- |
| New Jersey | 16,198 | 16,800 | 16,475 | W | W |
| New Mexico | W | -- | -- | -- | -- |
| New York | 36,889 | 52,287 | 56,748 | W | W |
| Pennsylvania | 24,732 | 24,762 | 16,792 | -- | -- |
| Tennessee | 117,684 | 121,306 | 109,958 | 116,526 | 104,471 |
| Utah | 1,576 | -- | -- | W | -- |
| Virginia | 9,731 | -- | -- | -- | -- |
| Total | 312,418 | 303,160 | 275,294 | 252,768 | 226,545 |

W Withheld to avoid disclosing company proprietary data; included in "Total."

## Table 5.—Production of zinc and lead in the United States in 1985, by State and class of ore, from old tailings, etc., in terms of recoverable metals

(Metric tons)

| State | Zinc ore | | | Lead ore | | | Zinc-lead ore | | |
|---|---|---|---|---|---|---|---|---|---|
| | Gross weight (dry basis) | Zinc | Lead | Gross weight (dry basis) | Zinc | Lead | Gross weight (dry basis) | Zinc | Lead |
| Arizona | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Colorado | -- | -- | -- | -- | -- | -- | W | W | W |
| Idaho | -- | -- | -- | -- | -- | -- | W | W | W |
| Illinois | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Kentucky | W | W | -- | -- | -- | -- | -- | -- | -- |
| Missouri | -- | -- | -- | 6,433,706 | 49,340 | 371,008 | -- | -- | -- |
| Montana | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Nevada | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| New Jersey | W | W | -- | -- | -- | -- | -- | -- | -- |
| New Mexico | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| New York | W | W | W | -- | -- | -- | -- | -- | -- |
| Tennessee | W | W | W | -- | -- | -- | -- | -- | -- |
| Total | 4,261,858 | 161,580 | (1) | 6,433,706 | 49,340 | 371,008 | (1) | (1) | (1) |
| Percent of total zinc or lead | XX | 71 | (1) | XX | 22 | 90 | XX | (1) | (1) |

| State | Copper-zinc, copper-lead, copper-zinc-lead ores | | | All other sources[2] [3] | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Gross weight (dry basis) | Zinc | Lead | Gross weight (dry basis) | Zinc | Lead | Gross weight (dry basis) | Zinc | Lead |
| Arizona | -- | -- | -- | 51,010,198 | -- | 581 | 51,010,198 | -- | 581 |
| Colorado | -- | -- | -- | 37,508 | W | 643 | W | W | W |
| Idaho | -- | -- | -- | W | W | W | [3]901,337 | W | 33,707 |
| Illinois | -- | -- | -- | -- | W | W | (3) | W | W |
| Kentucky | -- | -- | -- | -- | -- | -- | W | W | -- |
| Missouri | -- | -- | -- | -- | -- | -- | 6,433,706 | 49,340 | 371,008 |
| Montana | -- | -- | -- | 2,616,424 | -- | 846 | 2,616,424 | -- | 846 |
| Nevada | -- | -- | -- | 73 | -- | (4) | 73 | -- | (4) |
| New Jersey | -- | -- | -- | -- | -- | -- | W | W | -- |
| New Mexico | -- | -- | -- | W | -- | W | W | -- | W |
| New York | -- | -- | -- | -- | -- | -- | W | W | W |
| Tennessee | -- | -- | -- | W | W | -- | 5,373,817 | 104,471 | W |
| Total | -- | -- | -- | 56,435,942 | 15,675 | 42,947 | 67,131,506 | 226,545 | 413,955 |
| Percent of total zinc or lead | XX | -- | -- | XX | 7 | 10 | XX | 100 | 100 |

W Withheld to avoid disclosing company proprietary data; included in "Total." XX Not applicable.

[1] Included with "All other sources" to avoid disclosing company proprietary data.

[2] Includes zinc and lead recovered from zinc-lead ores in Colorado and Idaho and lead from zinc ores in New York and Tennessee in order to avoid disclosing company proprietary data. Also includes zinc and lead recovered from copper, gold, gold-silver, and molybdenum ores; from fluorspar; and from mill tailings.

[3] Excludes tonnages of fluorspar in Illinois from which zinc and lead were recovered as byproducts, and molybdenum ore in Idaho from which lead was recovered as a byproduct.

[4] Less than 1/2 unit.

## Table 6.—Twenty-five leading zinc-producing mines in the United States in 1985, in order of output

| Rank | Mine | County and State | Operator | Source of zinc |
|---|---|---|---|---|
| 1 | Elwood-Gordonsville | Smith, TN | Jersey Minière Zinc Co | Zinc ore. |
| 2 | Buick | Iron, MO | AMAX Lead Co. of Missouri | Lead ore. |
| 3 | Balmat | St. Lawrence, NY | St. Joe Minerals Corp | Zinc ore. |
| 4 | Pierrepont | do | do | Do. |
| 5 | Magmont | Iron, MO | Cominco American Incorporated. | Lead ore. |
| 6 | Zinc Mine Works | Jefferson, TN | United States Steel Corp | Zinc ore. |
| 7 | Sterling | Sussex, NJ | The New Jersey Zinc Co. Inc | Do. |
| 8 | Young | Jefferson, TN | ASARCO Incorporated | Do. |
| 9 | Leadville unit | Lake, CO | do | Lead-zinc ore. |
| 10 | Beaver Creek | Jefferson, TN | Inspiration Mines Inc | Zinc ore. |
| 11 | New Market | do | ASARCO Incorporated | Do. |
| 12 | Immel | Knox, TN | do | Do. |
| 13 | Viburnum No. 29 | Washington, MO | St. Joe Minerals Corp | Lead ore. |
| 14 | Lucky Friday | Shoshone, ID | Hecla Mining Co | Silver ore. |
| 15 | Coy | Jefferson, TN | ASARCO Incorporated | Zinc ore. |
| 16 | Fletcher | Reynolds, MO | St. Joe Minerals Corp | Lead ore. |
| 17 | Star-Morning | Shoshone, ID | Star-Morning Mining Co | Silver ore. |
| 18 | Casteel | Iron, MO | St. Joe Minerals Corp | Lead ore. |
| 19 | Rosiclare | Hardin and Pope, IL | Ozark-Mahoning Co | Fluorspar. |
| 20 | Viburnum No. 28 | Iron, MO | St. Joe Minerals Corp | Lead ore. |
| 21 | Copperhill | Polk, TN | Tennessee Chemical Co | Copper-zinc ore. |
| 22 | Sunnyside | San Juan, CO | Standard Metals Corp | Gold ore. |
| 23 | Black Pine | Granite, MT | Black Pine Mining Co | Silver ore. |
| 24 | West Fork | Reynolds, MO | ASARCO Incorporated | Lead ore. |
| 25 | Clayton | Custer, ID | Clayton Silver Mines Inc | Silver ore. |

## Table 7.—Primary and redistilled secondary slab zinc produced in the United States

(Metric tons)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Primary: | | | | | |
| From domestic ores | 259,835 | 193,284 | 210,315 | 197,912 | 172,773 |
| From foreign ores | 86,728 | 34,892 | 25,379 | 55,220 | 63,204 |
| Total | 346,563 | 228,176 | 235,694 | 253,132 | 235,977 |
| Redistilled secondary: | | | | | |
| At primary smelters | 14,438 | 42,418 | 40,545 | 44,930 | 42,730 |
| At secondary smelters | 35,754 | 31,870 | 28,845 | 33,183 | 32,844 |
| Total | 50,192 | 74,288 | 69,390 | 78,113 | 75,574 |
| Grand total (excludes zinc recovered by remelting) | 396,755 | 302,464 | 305,084 | 331,245 | 311,551 |

## Table 8.—Distilled and electrolytic zinc, primary and secondary, produced in the United States, by grade

(Metric tons)

| Grade | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Special High | 137,210 | 112,648 | 95,396 | 123,325 | 98,282 |
| High | 51,990 | 81,076 | 78,511 | 71,892 | 95,465 |
| Continuous Galvanizing | 55,008 | 57,789 | 50,661 | 48,200 | 26,129 |
| Controlled Lead | 38,660 | 7,612 | 10,231 | 9,384 | 20,962 |
| Prime Western | 113,887 | 93,339 | 70,286 | 78,444 | 70,713 |
| Total | 396,755 | 302,464 | 305,084 | 331,245 | 311,551 |

## Table 9.—Annual slab zinc capacity of primary zinc plants in the United States, by type of plant and company

| Type of plant and company | Plant location | Slab zinc capacity (metric tons) 1984 | Slab zinc capacity (metric tons) 1985 |
|---|---|---|---|
| Electrolytic: | | | |
| AMAX Inc | Sauget, IL | 76,000 | 76,000 |
| ASARCO Incorporated[1] | Corpus Christi, TX | 104,000 | 104,000 |
| Bunker Ltd.[2] | Kellogg, ID | 103,000 | -- |
| Jersey Minière Zinc Co | Clarksville, TN | 82,000 | 82,000 |
| St. Joe Resources Corp | Bartlesville, OK | 51,000 | 51,000 |
| Electrothermic: | | | |
| St. Joe Resources Corp | Monaca, PA | 91,000 | 91,000 |

[1] Zinc plant reopened in May 1984 closed indefinitely in Apr. 1985.
[2] Zinc plant closed in Dec. 1981, permanently closed in 1985.

## Table 10.—Secondary slab zinc plant capacity in the United States, by company

| Company | Plant location | Capacity (metric tons) 1984 | Capacity (metric tons) 1985 |
|---|---|---|---|
| ARCO Alloys Corp | Detroit, MI | 95,000 | 95,000 |
| W. J. Bullock Inc | Fairfield, AL | | |
| T. L. Diamond & Co. Inc | Spelter, WV | | |
| Gulf Reduction Corp | Houston, TX | | |
| Hugo Neu-Proler Co | Terminal Island, CA | | |
| Huron Valley Steel Corp | Belleville, MI | | |
| Interamerican Zinc Co | Adrian, MI | | |
| The New Jersey Zinc Co. Inc | Palmerton, PA | | |
| Pacific Smelting Co | Torrance, CA | | |
| Do | Memphis, TN | | |
| Prolerized Schiabo Neu Co | Jersey City, NJ | | |

## Table 11.—Stocks and consumption of new and old zinc scrap in the United States in 1985, by class of consumer and type of scrap

(Metric tons, zinc content)

| Class of consumer and type of scrap | Stocks, Jan. 1 | Receipts | Consumption: New scrap | Consumption: Old scrap | Consumption: Total | Stocks, Dec. 31 |
|---|---|---|---|---|---|---|
| Smelters and distillers: | | | | | | |
| New clippings | 27 | 779 | 650 | -- | 650 | 156 |
| Old zinc | 400 | 1,128 | -- | 1,400 | 1,400 | 128 |
| Remelt zinc | 135 | 6,630 | 6,635 | -- | 6,635 | 130 |
| Engraver's plates | W | 583 | -- | 585 | 585 | W |
| Rod and die scrap | 992 | 2,256 | -- | 2,305 | 2,305 | 943 |
| Diecastings | 1,586 | 11,090 | -- | 11,513 | 11,513 | 1,163 |
| Fragmentized diecastings | W | 27,668 | -- | 27,711 | 27,711 | W |
| Remelt die-cast slab | 642 | 8,662 | -- | 8,800 | 8,800 | 504 |
| Skimmings and ashes | 32,904 | 72,370 | 79,626 | -- | 79,626 | 25,648 |
| Sal skimmings | W | 2,651 | 2,670 | -- | 2,670 | W |
| Die-cast skimmings | 2,011 | 5,968 | 7,134 | -- | 7,134 | 845 |
| Galvanizer's dross | 8,016 | 44,061 | 42,151 | -- | 42,151 | 9,926 |
| Flue dust | 3,235 | 4,792 | 4,915 | -- | 4,915 | 3,112 |
| Chemical residues | W | W | W | -- | W | W |
| Other | W | 589 | 652 | -- | 652 | W |
| Total | 53,581 | 190,522 | 145,777 | 52,314 | 198,091 | 46,012 |
| Chemical plants, foundries, other manufacturers: | | | | | | |
| Old zinc | W | W | W | W | W | W |
| Diecastings | W | W | W | W | W | W |
| Skimmings and ashes | W | 4,631 | 4,474 | -- | 4,474 | W |
| Sal skimmings | W | 2,863 | 2,359 | -- | 2,359 | W |
| Galvanizer's dross | W | W | W | W | W | W |
| Flue dust | W | 11,832 | 11,503 | -- | 11,503 | W |
| Chemical residues | W | W | W | W | W | W |
| Other | W | W | W | W | W | W |
| Total | 2,835 | 21,354 | 20,005 | 359 | 20,364 | 3,825 |
| Grand Total | 56,416 | 211,876 | 165,782 | 52,673 | 218,455 | 49,837 |

W Withheld to avoid disclosing company proprietary data; included in "Total."

## Table 12.—Production of zinc products from zinc-base scrap in the United States

(Metric tons)

| Product | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Redistilled slab zinc | 50,192 | 74,288 | 69,890 | 78,113 | 75,574 |
| Zinc dust | 39,626 | 25,296 | 34,773 | 40,697 | 36,899 |
| Remelt zinc | 195 | 69 | 66 | 71 | -- |
| Remelt die-cast slab | 6,722 | 3,905 | 3,109 | 3,380 | 3,069 |
| Zinc die and diecasting alloys | 6,902 | 5,366 | 6,535 | 6,112 | 5,687 |
| Galvanizing stocks | 2,612 | 2,507 | 2,801 | 2,868 | W |
| Secondary zinc in chemical products | 62,557 | 61,827 | 59,085 | ʳ66,221 | 55,808 |

ʳRevised. W Withheld to avoid disclosing company proprietary data.

## Table 13.—Zinc recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Metric tons)

|  | 1984 | 1985 |
|---|---|---|
| KIND OF SCRAP |  |  |
| New scrap: |  |  |
| Zinc-base | 182,976 | 165,461 |
| Copper-base | 134,699 | 125,173 |
| Magnesium-base | 130 | 68 |
| Total | 317,805 | 290,702 |
| Old scrap: |  |  |
| Zinc-base | 55,447 | 51,788 |
| Copper-base | 24,763 | 22,016 |
| Aluminum-base | 334 | 294 |
| Magnesium-base | 220 | 214 |
| Total | 80,764 | 74,312 |
| Grand total | 398,569 | 365,014 |
| FORM OF RECOVERY |  |  |
| As metal: |  |  |
| By distillation: |  |  |
| Slab zinc[1] | 78,113 | 75,574 |
| Zinc dust | 40,697 | 36,899 |
| By remelting | 2,438 | 1,112 |
| Total | 121,248 | 113,585 |
| In zinc-base alloys | 9,492 | 8,726 |
| In brass and bronze | ʳ200,792 | 186,281 |
| In aluminum-base alloys | 466 | 332 |
| In magnesium-base alloys | 350 | 282 |
| In chemical products: |  |  |
| Zinc oxide (lead free) | 40,072 | 32,036 |
| Zinc sulfate | 18,687 | 15,506 |
| Zinc chloride | 12,398 | 7,841 |
| Miscellaneous | ʳ64 | 425 |
| Total | 277,321 | 251,429 |
| Grand total | 398,569 | 365,014 |

ʳRevised.

[1] Includes zinc content of redistilled slab made from remelt die-cast slab.

## Table 14.—U.S. production of zinc dust[1]

| Year | Quantity (metric tons) | Value: Total (thousands) | Value: Average per pound |
|---|---|---|---|
| 1981 | 43,734 | $53,801 | $0.558 |
| 1982 | 37,516 | 49,327 | .596 |
| 1983 | 40,508 | 45,849 | .513 |
| 1984 | 46,487 | 67,846 | .662 |
| 1985 | 29,542 | 37,123 | .570 |

[1] Does not include zinc dust produced for internal plant use.

## Table 15.—U.S. consumption of zinc

(Metric tons)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Slab zinc reported | 840,875 | 709,491 | 805,891 | 848,903 | 764,752 |
| Ores and concentrates (zinc content)[1] | 60,643 | 35,515 | 38,287 | 47,637 | 42,284 |
| Secondary (zinc content)[2] | 287,851 | 208,105 | 276,370 | 318,018 | 288,328 |
| Total | 1,189,369 | 953,111 | 1,120,548 | 1,214,558 | 1,095,364 |

[1] Includes ore used directly in galvanizing.
[2] Excludes redistilled slab and remelt zinc.

## Table 16.—U.S. reported consumption of slab zinc in 1985, by industry and grade

(Metric tons)

| Industry | Special High Grade | High Grade | Continuous Galvanizing Grade | Controlled Lead Grade | Prime Western | Remelt | Total |
|---|---|---|---|---|---|---|---|
| Galvanizing | 69,807 | 65,884 | 37,109 | 25,036 | 161,776 | 1,741 | 361,353 |
| Zinc-base alloys | 216,864 | 1,428 | -- | -- | 21 | -- | 218,313 |
| Brass and bronze | 43,897 | 17,679 | 22 | 129 | 12,409 | 3,784 | 77,920 |
| Rolled zinc | 33,889 | -- | -- | 14,131 | -- | -- | 48,020 |
| Zinc oxide | 39,183 | 479 | -- | -- | -- | -- | 39,662 |
| Other | 16,912 | 1,939 | -- | -- | 633 | -- | 19,484 |
| Total | 420,552 | 87,409 | 37,131 | 39,296 | 174,839 | 5,525 | 764,752 |

## Table 17.—U.S. consumption of slab zinc, by industry and product

(Metric tons)

| Industry and product | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Galvanizing: | | | | | |
| Sheet and strip | 248,006 | 204,519 | 230,541 | 222,872 | 226,489 |
| Wire and wire rope | 22,119 | 17,180 | 18,328 | 18,430 | 14,437 |
| Tubes and pipe | 39,418 | 34,322 | 34,907 | 39,463 | 27,580 |
| Fittings (for tubes and pipe) | 6,369 | 5,707 | 5,990 | 4,446 | 3,830 |
| Tanks and containers | 5,781 | 6,507 | 4,195 | 4,044 | 5,442 |
| Structural shapes | 33,667 | 28,816 | 29,822 | 35,494 | 31,444 |
| Fasteners | 3,693 | 2,898 | 2,614 | 2,518 | 6,411 |
| Pole-line hardware | 3,788 | 2,955 | 3,013 | 3,326 | 3,755 |
| Fencing, wire cloth, netting | 17,722 | 17,330 | 15,916 | 12,644 | 13,319 |
| Other and unspecified uses | 30,484 | 21,810 | 27,853 | 32,386 | 28,646 |
| Total | 411,047 | 342,044 | 373,179 | 375,623 | 361,353 |
| Brass and bronze products: | | | | | |
| Sheet, strip, plate | 42,006 | 31,718 | 43,083 | 55,583 | 30,487 |
| Rod and wire | 36,639 | 26,551 | 32,387 | 34,231 | 17,814 |
| Tubes | 6,440 | 3,465 | 4,058 | 4,750 | 2,705 |
| Castings and billets | 2,880 | 2,211 | 7,499 | 9,726 | 12,183 |
| Copper-base ingots | 20,167 | 13,278 | 16,405 | 19,446 | 13,986 |
| Other copper-base products | 4,854 | 3,915 | 4,503 | 1,858 | 745 |
| Total | 112,986 | 81,138 | 107,935 | 125,594 | 77,920 |
| Zinc-base alloys: | | | | | |
| Diecasting alloys | 234,957 | 191,607 | 204,820 | 216,306 | 205,388 |
| Dies and rod alloys | -- | -- | -- | 1,666 | 2,552 |
| Slush and sand-casting alloys | 8,408 | 6,147 | 8,071 | 14,660 | 10,373 |
| Total | 243,365 | 197,754 | 212,891 | 232,632 | 218,313 |
| Rolled zinc[1] | 23,156 | 37,168 | 56,291 | 56,886 | 48,020 |
| Zinc oxide | 25,657 | 32,374 | 36,201 | 37,038 | 39,662 |
| Other: | | | | | |
| Light-metal alloys | 8,183 | 8,326 | 12,538 | 14,922 | 15,204 |
| Miscellaneous[2] | 16,481 | 10,687 | 6,856 | 6,208 | 4,280 |
| Total | 24,664 | 19,013 | 19,394 | 21,130 | 19,484 |
| Grand total | 840,875 | 709,491 | 805,891 | 848,903 | 764,752 |

[1] Includes zinc used in penny production.
[2] Includes zinc used in making zinc dust, wet batteries, desilverizing lead, powder, alloys, chemicals, castings, and miscellaneous uses not elsewhere mentioned.

## Table 18.—U.S. consumption of slab zinc in 1985, by State

(Metric tons)

| State | Galvanizers | Brass mills[1] | Diecasters[2] | Other[3] | Total |
|---|---|---|---|---|---|
| Alabama | W | W | -- | -- | 19,336 |
| Arkansas | W | -- | -- | W | W |
| California | 27,771 | 1,060 | -- | 3,841 | 32,672 |
| Colorado | W | -- | W | W | W |
| Connecticut | 2,853 | 5,030 | W | W | 13,428 |
| Delaware | W | -- | -- | -- | W |
| Florida | W | -- | -- | -- | W |
| Georgia | W | -- | W | -- | 7,110 |
| Hawaii | W | -- | -- | -- | W |
| Illinois | 53,425 | 13,301 | 24,111 | 11,926 | 102,763 |
| Indiana | 68,522 | W | W | W | 84,719 |
| Iowa | -- | -- | W | W | W |
| Kansas | -- | -- | W | -- | W |
| Kentucky | 16,550 | -- | -- | -- | 16,550 |
| Louisiana | W | -- | W | -- | 2,545 |
| Maine | W | -- | -- | -- | W |
| Maryland | 11,359 | -- | -- | -- | 11,359 |
| Massachusetts | 2,481 | W | -- | W | 3,148 |
| Michigan | 602 | W | 50,985 | W | 55,744 |
| Minnesota | 654 | -- | -- | -- | 654 |
| Mississippi | W | -- | -- | -- | W |
| Missouri | W | -- | -- | W | 3,552 |
| Nebraska | W | -- | -- | W | 6,056 |
| New Jersey | 1,518 | W | W | W | 9,320 |
| New York | 4,409 | W | 88,565 | W | 113,749 |
| North Carolina | W | -- | W | -- | W |
| Ohio | 34,257 | W | 32,574 | W | 76,754 |
| Oklahoma | W | -- | -- | W | 3,118 |
| Oregon | W | -- | W | W | 1,353 |
| Pennsylvania | 47,466 | 6,263 | W | W | 80,102 |
| South Carolina | W | -- | -- | -- | W |
| Tennessee | 838 | -- | W | W | 48,234 |
| Texas | 10,556 | -- | W | W | 10,715 |
| Utah | W | -- | -- | -- | W |
| Virginia | W | W | W | -- | 4,611 |
| Washington | W | -- | -- | W | 1,906 |
| West Virginia | W | -- | -- | W | 22,310 |
| Wisconsin | 725 | 757 | W | W | 7,917 |
| Undistributed | 75,625 | 47,723 | 22,080 | 91,400 | 19,502 |
| Total[4] | 359,611 | 74,184 | 218,315 | 107,167 | 759,227 |

W Withheld to avoid disclosing company proprietary data; included with "Total" and "Undistributed."

[1] Includes brass mills, brass ingot makers, and brass foundries.

[2] Includes producers of zinc-base alloys for diecastings, stamping dies, and rods.

[3] Includes slab zinc used in rolled zinc products and in zinc oxide.

[4] Excludes remelt zinc.

## Table 19.—Rolled zinc produced and quantity available for consumption in the United States

(Metric tons)

| | 1984 | 1985 |
|---|---|---|
| Production[1] | 55,633 | 46,641 |
| Exports | 975 | 776 |
| Imports | 850 | 943 |
| Available for consumption | 52,343 | 48,119 |

[1] Figures represent net production. In addition, 40,855 tons in 1984 and 37,755 tons in 1985 were rerolled from scrap originating in fabricating plants operating in connection with zinc-rolling mills. Includes other plate over 0.375 inch thick, sheet zinc less than 0.375 inch thick, and rod and wire. The Bureau of Mines is not at liberty to publish separately

## Table 20.—Production and shipments of zinc pigments and compounds[1] in the United States

(Metric tons)

| | 1984 | | 1985 | |
|---|---|---|---|---|
| | Production | Shipments | Production | Shipments |
| Zinc oxide | 150,623 | 146,918 | 137,382 | 136,129 |
| Zinc sulfate | 37,408 | 37,112 | 42,316 | 42,509 |
| Zinc chloride[2] | 25,664 | 26,705 | 20,546 | 20,041 |

[1] Excludes leaded zinc oxide and lithopone.
[2] Includes zinc content of zinc ammonium chloride.

## Table 21.—Zinc content of zinc pigments[1] and compounds produced by domestic manufacturers, by source

(Metric tons)

| | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|
| | Zinc in pigments and compounds produced from— | | | Total | Zinc in pigments and compounds produced from— | | | Total |
| | Ore | Slab zinc | Secondary material | | Ore | Slab zinc | Secondary material | |
| Zinc oxide | 43,450 | 37,038 | 40,072 | 120,560 | 38,168 | 39,662 | 32,036 | 109,866 |
| Zinc sulfate | W | -- | 15,150 | 15,150 | W | -- | 17,138 | 17,138 |
| Zinc chloride[2] | -- | -- | [r]12,453 | [r]12,453 | -- | -- | 9,782 | 9,782 |

[r] Revised. W Withheld to avoid disclosing company proprietary data; included with "Secondary material."
[1] Excludes leaded zinc oxide, zinc sulfide, and lithopone.
[2] Includes zinc content of zinc ammonium chloride.

## Table 22.—Distribution of zinc oxide shipments, by industry

(Metric tons)

| Industry | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Agriculture | 7,328 | 3,929 | 2,569 | 2,380 | 2,575 |
| Ceramics | 7,822 | 5,215 | 5,987 | 7,472 | 7,283 |
| Chemicals | 20,561 | 19,432 | 19,217 | 23,611 | 22,466 |
| Paints | 12,346 | 9,283 | 9,716 | 8,117 | 8,215 |
| Photocopying | 10,308 | 9,516 | 10,239 | 9,246 | 8,323 |
| Rubber | 69,364 | 62,923 | 67,971 | 79,390 | 71,552 |
| Other | 21,222 | 17,136 | 19,355 | 16,702 | 15,715 |
| Total | 148,951 | 127,434 | 135,054 | 146,918 | 136,129 |

## Table 23.—Distribution of zinc sulfate shipments

(Metric tons)

| Year | Agriculture | Other | Total |
|---|---|---|---|
| 1982 | 29,882 | 9,040 | 38,922 |
| 1983 | 29,373 | 5,613 | 34,986 |
| 1984 | 28,162 | 8,950 | 37,112 |
| 1985 | 33,786 | 8,723 | 42,509 |

## Table 24.—Stocks of slab zinc in the United States, December 31

(Metric tons)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Primary producers | 41,124 | 30,381 | 20,750 | 42,025 | 29,030 |
| Secondary producers | 3,540 | 3,831 | 3,149 | 4,303 | 3,389 |
| Consumers | 81,917 | 77,565 | 89,041 | 72,506 | 58,923 |
| Merchants | 68,773 | 47,397 | 35,199 | 18,792 | 27,163 |
| Total | 195,354 | 159,174 | 148,139 | 137,626 | 118,505 |

### Table 25.—Consumer stocks of slab zinc at plants in the United States, December 31, by grade

(Metric tons)

| Year | Special High Grade | High Grade | Continuous Galvanizing Grade | Controlled Lead Grade | Prime Western | Remelt | Total |
|---|---|---|---|---|---|---|---|
| 1984 | 40,296 | 6,310 | 3,963 | 2,284 | 19,437 | 216 | 72,506 |
| 1985 | 32,485 | 5,757 | 941 | 2,187 | 17,416 | 137 | 58,923 |

### Table 26.—Average monthly U.S., LME,[1] and European producer prices for Prime Western zinc and equivalent

(Metallic zinc, cents per pound)

| Month | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | United States[2] | LME cash | European producer | United States[2] | LME cash | European producer |
| January | 49.22 | 43.41 | 44.45 | 42.94 | 39.20 | 40.82 |
| February | 50.61 | 45.26 | 47.63 | 42.65 | 40.14 | 40.82 |
| March | 51.07 | 47.16 | 47.63 | 43.20 | 41.70 | 41.90 |
| April | 51.90 | 45.52 | 49.44 | 44.88 | 42.14 | 43.54 |
| May | 52.77 | 45.38 | 49.44 | 45.12 | 39.87 | 42.99 |
| June | 52.45 | 42.67 | 48.90 | 43.73 | 36.56 | 40.48 |
| July | 49.52 | 38.70 | 45.34 | 41.44 | 34.70 | 38.06 |
| August | 47.85 | 37.81 | 44.91 | 39.84 | 33.29 | 37.14 |
| September | 46.42 | 39.31 | 43.12 | 37.86 | 31.24 | 35.88 |
| October | 44.19 | 38.09 | 40.64 | 35.76 | 28.62 | 33.53 |
| November | 43.60 | 38.67 | 40.82 | 33.36 | 27.06 | 30.10 |
| December | 43.62 | 38.87 | 40.82 | 33.61 | 31.05 | 30.56 |
| Average | 48.60 | 40.46 | 45.30 | 40.37 | 36.23 | 37.94 |

[1] London Metal Exchange.
[2] Based on High Grade zinc delivered.

Source: Metals Week.

### Table 27.—U.S. exports of zinc and zinc alloys, by country

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| **Unwrought zinc and zinc alloys:** | | | | | | |
| Australia | 12 | $46 | (1) | $2 | -- | -- |
| Belgium-Luxembourg | (1) | 2 | (1) | 1 | 20 | $22 |
| Canada | 416 | 762 | 88 | 222 | 432 | 925 |
| Chile | 3 | 57 | 398 | 419 | 501 | 451 |
| Costa Rica | 12 | 21 | 5 | 12 | 7 | 9 |
| Egypt | -- | -- | 1 | 4 | 255 | 250 |
| Germany, Federal Republic of | 1 | 2 | 16 | 85 | 21 | 18 |
| Ghana | -- | -- | -- | -- | 26 | 26 |
| India | -- | -- | -- | -- | 48 | 62 |
| Israel | -- | -- | 1 | 3 | 25 | 56 |
| Japan | 28 | 76 | 166 | 220 | 37 | 73 |
| Korea, Republic of | 15 | 56 | 108 | 96 | 87 | 98 |
| Mexico | 4 | 17 | 73 | 137 | 79 | 207 |
| Netherlands | -- | -- | (1) | 1 | 27 | 67 |
| Panama | 10 | 17 | 40 | 63 | 5 | 9 |
| Saudi Arabia | 108 | 277 | 6 | 14 | 1 | 2 |
| Singapore | 40 | 131 | 2 | 4 | 18 | 39 |
| Spain | -- | -- | 22 | 24 | | |
| Switzerland | 72 | 377 | 2 | 6 | 1 | 1 |
| Taiwan | 288 | 260 | 361 | 332 | 618 | 453 |
| United Kingdom | 41 | 181 | 8 | 34 | 12 | 40 |
| Venezuela | 4 | 14 | 2 | 4 | 20 | 63 |
| Other[3] | r35 | r99 | r49 | r165 | 11 | 54 |
| Total | 1,089 | 2,395 | 1,348 | 1,798 | 2,251 | 2,936 |
| **Wrought zinc and zinc alloys:** | | | | | | |
| Argentina | 17 | 38 | 19 | 53 | 17 | 47 |
| Australia | 8 | 26 | 6 | 13 | 1 | 2 |

See footnotes at end of table.

## Table 27.—U.S. exports of zinc and zinc alloys, by country —Continued

| Country | 1983 Quantity (metric tons) | 1983 Value (thousands) | 1984 Quantity (metric tons) | 1984 Value (thousands) | 1985 Quantity (metric tons) | 1985 Value (thousands) |
|---|---|---|---|---|---|---|
| Wrought zinc and zinc alloys — Continued | | | | | | |
| Bahamas | 8 | $12 | 46 | $53 | 41 | $52 |
| Belgium-Luxembourg | 2 | 14 | 1 | 6 | -- | -- |
| Brazil | -- | -- | 37 | 71 | -- | -- |
| Canada | 1,221 | 1,762 | 769 | 1,571 | 1,379 | 2,085 |
| Chile | 3 | 4 | -- | -- | 11 | 80 |
| Colombia | 14 | 42 | 24 | 56 | 13 | 56 |
| Dominican Republic | 9 | 10 | 8 | 29 | 11 | 45 |
| Ecuador | 9 | 30 | 12 | 35 | 20 | 41 |
| Egypt | 11 | 25 | 1 | 4 | 6 | 17 |
| El Salvador | 12 | 36 | 3 | 14 | 6 | 18 |
| France | 5 | 9 | 4 | 6 | 23 | 69 |
| Guyana | 5 | 11 | 5 | 9 | 4 | 11 |
| India | 9 | 22 | 19 | 21 | -- | -- |
| Italy | -- | -- | 1 | 3 | -- | -- |
| Japan | 39 | 55 | 15 | 25 | 9 | 24 |
| Korea, Republic of | ([1]) | 1 | ([1]) | 2 | 14 | 34 |
| Leeward and Windward Islands | 25 | 22 | 48 | 33 | 1 | 1 |
| Libya | 119 | 340 | 1 | 1 | 8 | 7 |
| Mexico | 147 | 395 | 387 | 932 | 397 | 821 |
| Netherlands Antilles | 2 | 16 | 19 | 23 | 6 | 4 |
| Nicaragua | 25 | 42 | 4 | 14 | -- | -- |
| Pakistan | 3 | 8 | 1 | 4 | -- | -- |
| Panama | 1 | 3 | 4 | 10 | 20 | 41 |
| Philippines | 34 | 108 | 12 | 33 | 8 | 9 |
| Saudi Arabia | 28 | 72 | 9 | 16 | 2 | 24 |
| Singapore | 4 | 20 | 3 | 15 | 1 | 1 |
| South Africa, Republic of | 18 | 42 | 95 | 203 | 11 | 26 |
| Suriname | -- | -- | -- | -- | 8 | 21 |
| Switzerland | -- | -- | 46 | 130 | 17 | 68 |
| Taiwan | 72 | 123 | 92 | 177 | 34 | 83 |
| Trinidad and Tobago | -- | -- | 15 | 42 | 27 | 35 |
| United Kingdom | 90 | 218 | 33 | 142 | 48 | 41 |
| Venezuela | 5 | 12 | 4 | 21 | 33 | 182 |
| Zimbabwe | -- | -- | 36 | 79 | -- | -- |
| Other[3] | [r]63 | [r]287 | [r]41 | [r]101 | 44 | 131 |
| Total | 2,003 | 3,805 | 1,815 | 3,947 | 2,210 | 4,071 |

[r] Revised.

[1] Less than 1/2 unit.

[2] Includes Argentina, Barbados, Dominican Republic, Ecuador, El Salvador, France, Guatemala, Honduras, Hong Kong, Italy, Leeward and Windward Islands, Libya, Netherlands Antilles, New Zealand, Peru, Philippines, the Republic of South Africa, and the United Arab Emirates.

[3] Includes Austria, Belize, Bermuda, China, Costa Rica, Denmark, Finland, French Guiana, the Federal Republic of Germany, Ghana, Guatemala, Hong Kong, Iran, Israel, Jamaica, Kuwait, Morocco, the Netherlands, New Zealand, Norway, Peru, Portugal, Qatar, Somalia, Sri Lanka, Turkey, the United Arab Emirates, and Uruguay.

Source: Bureau of the Census.

## Table 28.—U.S. exports of zinc

| Year | Ores and concentrates | | Blocks, pigs, anodes, etc. | | | |
|---|---|---|---|---|---|---|
| | | | Unwrought | | Unwrought alloys | |
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1983 | 60,168 | $22,868 | 427 | $801 | 662 | $1,594 |
| 1984 | 30,579 | 18,858 | 760 | 975 | 588 | 823 |
| 1985 | 23,264 | 8,216 | 1,011 | 1,525 | 1,240 | 1,402 |

| Year | Wrought zinc and zinc alloys | | | | Waste and scrap (zinc content) | | Dust (blue powder) | |
|---|---|---|---|---|---|---|---|---|
| | Sheets, plates, strips | | Angles, bars, pipes, rods, etc. | | | | | |
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1983 | 957 | $2,142 | 1,046 | $1,663 | 28,255 | $15,389 | 1,914 | $3,000 |
| 1984 | 975 | 2,421 | 840 | 1,526 | 39,146 | 20,360 | 2,933 | 3,511 |
| 1985 | 776 | 1,973 | 1,434 | 2,098 | 43,947 | 19,600 | 2,037 | 2,480 |

Source: Bureau of the Census.

### Table 29.—U.S. exports of zinc ores and concentrates, by country

(Zinc content)

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Bulgaria | 3,028 | $1,801 | -- | -- |
| Canada | 19,102 | 8,360 | 6,141 | $3,226 |
| France | -- | -- | 3,793 | 426 |
| Germany, Federal Republic of | -- | -- | 1,948 | 683 |
| India | 20 | 13 | -- | -- |
| Israel | -- | -- | 2 | 4 |
| Italy | -- | -- | 5,275 | 2,338 |
| Jamaica | 38 | 56 | -- | -- |
| Japan | -- | -- | 6,043 | 1,519 |
| Korea, Republic of | 33 | 19 | -- | -- |
| Mexico | 2,574 | 866 | -- | -- |
| Sweden | 1 | 3 | -- | -- |
| Taiwan | -- | -- | 62 | 20 |
| U.S.S.R | 5,783 | 2,235 | -- | -- |
| Total | 30,579 | 13,353 | 23,264 | 8,216 |

Source: Bureau of the Census.

### Table 30.—U.S. general imports of zinc, by country

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| ORES AND CONCENTRATES (zinc content) | | | | | | |
| Australia | 2,261 | $1,113 | 2,577 | $1,264 | 2,934 | $819 |
| Canada | 13,715 | 3,370 | 34,717 | 14,631 | 47,200 | 18,351 |
| Chile | 27 | 15 | -- | -- | -- | -- |
| Germany, Federal Republic of | 6,552 | 1,067 | -- | -- | -- | -- |
| Honduras | 12,632 | 3,920 | 10,352 | 4,365 | 14,302 | 4,175 |
| Mexico | 17,887 | 4,518 | 20,125 | 6,650 | 12,983 | 4,232 |
| Peru | 9,136 | 3,208 | 17,610 | 7,100 | 13,402 | 4,970 |
| South Africa, Republic of | -- | -- | 10,186 | 2,633 | 478 | 1,963 |
| United Kingdom | -- | -- | -- | -- | 92 | 64 |
| Total | 62,210 | 17,211 | 95,567 | 36,643 | 91,391 | 34,574 |
| BLOCKS, PIGS, OR SLABS[1] | | | | | | |
| Algeria | 2,051 | 1,846 | 403 | 374 | -- | -- |
| Argentina | -- | -- | -- | -- | 2,500 | 1,741 |
| Australia | 30,537 | 23,331 | 23,188 | 23,292 | 29,610 | 26,482 |
| Austria | 102 | 87 | -- | -- | -- | -- |
| Belgium-Luxembourg | 5,820 | 3,787 | 3,366 | 2,750 | 1,000 | 892 |
| Brazil | -- | -- | 3,280 | 4,260 | -- | -- |
| Canada | 307,156 | 263,145 | 340,380 | 351,715 | 383,618 | 326,386 |
| Congo | -- | -- | 1,311 | 1,032 | -- | -- |
| Finland | 25,402 | 20,614 | 15,953 | 16,197 | 19,601 | 16,832 |
| France | 8,932 | 6,858 | 12,923 | 12,807 | 5,410 | 4,027 |
| Germany, Federal Republic of | 29,675 | 23,645 | 27,930 | 27,543 | 11,991 | 11,937 |
| India | -- | -- | 99 | 84 | -- | -- |
| Italy | 11,913 | 9,483 | 13,719 | 12,270 | -- | -- |
| Japan | -- | -- | 3,000 | 3,050 | 2,700 | 2,386 |
| Mexico | 56,029 | 44,433 | 56,221 | 55,352 | 53,846 | 38,355 |
| Netherlands | 21,544 | 16,546 | 17,296 | 16,284 | 13,053 | 10,293 |
| Netherlands Antilles | 100 | 85 | -- | -- | -- | -- |
| Nigeria | 2,553 | 2,073 | -- | -- | -- | -- |
| Norway | 9,197 | 7,277 | 13,848 | 12,790 | 10,822 | 8,975 |
| Panama | -- | -- | -- | -- | 13 | 12 |
| Peru | 45,318 | 34,729 | 34,025 | 32,117 | 36,326 | 29,104 |
| Poland | 917 | 1,082 | 600 | 607 | 652 | 491 |
| Saudi Arabia | -- | -- | -- | -- | 39 | 25 |
| South Africa, Republic of | 1,000 | 644 | 998 | 1,054 | 3,696 | 2,753 |
| Spain | 18,728 | 14,453 | 16,907 | 16,476 | 17,058 | 13,370 |
| Sweden | 143 | 115 | 4,000 | 3,937 | -- | -- |
| Switzerland | -- | -- | 100 | 78 | -- | -- |
| Taiwan | -- | -- | -- | -- | 6 | 1 |
| Tanzania | 370 | 261 | 173 | 173 | -- | -- |
| United Kingdom | 9,602 | 7,387 | 5,685 | 5,251 | 6,779 | 5,320 |
| Yemen (Sanaa) | 127 | 100 | -- | -- | -- | -- |

See footnotes at end of table.

## Table 30.—U.S. general imports of zinc, by country —Continued

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| **BLOCKS, PIGS, OR SLABS[1] — Continued** | | | | | | |
| Yugoslavia | 1,558 | $1,247 | 2,467 | $2,251 | -- | -- |
| Zaire | 24,593 | 18,623 | 32,329 | 25,769 | 12,042 | $8,597 |
| Zambia | -- | -- | 2,476 | 2,291 | -- | -- |
| Total | 613,367 | 501,851 | 632,172 | 629,804 | 610,762 | 507,898 |

[1] In addition, in 1985, 332 tons of zinc anodes was imported from Australia, Canada, Denmark, India, Italy, Mexico, Norway, Sweden, Switzerland, Taiwan, Thailand, and the United Kingdom.

Source: Bureau of the Census.

## Table 31.—U.S. imports for consumption of zinc, by country

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| **ORES AND CONCENTRATES (zinc content)** | | | | | | |
| Australia | 858 | $114 | 1,683 | $307 | 1,936 | $256 |
| Canada | 17,165 | 4,895 | 27,467 | 9,533 | 50,031 | 20,017 |
| Chile | 27 | 15 | -- | -- | -- | -- |
| Germany, Federal Republic of | 6,552 | 1,067 | -- | -- | -- | -- |
| Honduras | 11,709 | 2,965 | 10,118 | 4,102 | 14,302 | 4,175 |
| Mexico | 17,988 | 4,536 | 20,113 | 6,639 | 12,900 | 4,149 |
| Peru | 8,857 | 2,956 | 16,605 | 5,972 | 10,452 | 3,002 |
| South Africa, Republic of | -- | -- | 10,186 | 2,633 | 473 | 1,963 |
| United Kingdom | -- | -- | -- | -- | 92 | 64 |
| Total | 63,156 | 16,548 | 86,172 | 29,186 | 90,186 | 33,626 |
| **BLOCKS, PIGS, OR SLABS[1]** | | | | | | |
| Algeria | 2,051 | 1,846 | 403 | 374 | -- | -- |
| Argentina | -- | -- | -- | -- | 2,500 | 1,741 |
| Australia | 30,537 | 23,331 | 23,188 | 23,292 | 29,610 | 26,483 |
| Austria | 102 | 87 | -- | -- | -- | -- |
| Belgium-Luxembourg | 5,820 | 3,787 | 3,366 | 2,750 | 1,000 | 802 |
| Brazil | -- | -- | 3,280 | 4,260 | -- | -- |
| Canada | 307,156 | 263,145 | 340,490 | 351,836 | 383,618 | 326,388 |
| Congo | -- | -- | 1,311 | 1,032 | -- | -- |
| Finland | 20,651 | 16,305 | 20,704 | 20,506 | 19,601 | 16,832 |
| France | 8,932 | 6,858 | 12,923 | 12,807 | 5,410 | 4,027 |
| Germany, Federal Republic of | 29,675 | 23,645 | 27,930 | 27,543 | 11,991 | 11,937 |
| India | -- | -- | 99 | 84 | -- | -- |
| Italy | 11,913 | 9,483 | 13,719 | 12,270 | -- | -- |
| Japan | 4,305 | 3,425 | 3,000 | 3,050 | 2,700 | 2,386 |
| Mexico | 59,568 | 46,706 | 58,416 | 57,058 | 53,984 | 38,460 |
| Netherlands | 21,544 | 16,546 | 17,296 | 16,284 | 13,053 | 10,293 |
| Netherlands Antilles | 100 | 85 | -- | -- | -- | -- |
| Nigeria | 2,553 | 2,073 | -- | -- | -- | -- |
| Norway | 9,966 | 7,847 | 13,348 | 12,790 | 10,822 | 8,975 |
| Panama | -- | -- | -- | -- | 13 | 12 |
| Peru | 45,318 | 34,729 | 34,025 | 32,117 | 36,326 | 29,104 |
| Poland | 917 | 1,082 | 600 | 607 | 652 | 491 |
| Saudi Arabia | -- | -- | -- | -- | 39 | 25 |
| South Africa, Republic of | 1,000 | 644 | 993 | 1,054 | 3,696 | 2,753 |
| Spain | 18,978 | 14,691 | 16,907 | 16,476 | 17,058 | 13,370 |
| Sweden | 143 | 115 | 4,000 | 3,937 | -- | -- |
| Switzerland | -- | -- | 100 | 78 | -- | -- |
| Taiwan | -- | -- | -- | -- | 6 | 7 |
| Tanzania | 370 | 261 | 173 | 173 | -- | -- |
| United Kingdom | 9,602 | 7,387 | 5,685 | 5,251 | 6,779 | 5,320 |
| Yemen (Sanaa) | 127 | 100 | -- | -- | -- | -- |
| Yugoslavia | 1,558 | 1,247 | 2,467 | 2,251 | -- | -- |
| Zaire | 24,793 | 18,463 | 32,329 | 25,769 | 12,042 | 8,597 |
| Zambia | -- | -- | 2,476 | 2,291 | -- | -- |
| Total | 617,679 | 503,888 | 639,228 | 635,940 | 610,900 | 508,003 |

[1] In addition, in 1985, 332 tons of zinc anodes was imported from Australia, Canada, Denmark, India, Italy, Mexico, Norway, Sweden, Switzerland, Taiwan, Thailand, and the United Kingdom.

Source: Bureau of the Census.

## Table 32.—U.S. imports for consumption of zinc

| | Ores and concentrates (zinc content) | | Blocks, pigs, slabs[1] | | Sheets, plates, strips, other forms | | Waste and scrap | |
|---|---|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1983 | 68,156 | $16,548 | 617,679 | $503,888 | 319 | $426 | 3,900 | $1,676 |
| 1984 | 86,172 | 29,186 | 639,228 | 635,940 | 850 | 1,308 | 6,259 | 3,940 |
| 1985 | 90,186 | 33,626 | 610,900 | 508,003 | 3,559 | 2,757 | 3,247 | 1,848 |

| | Dross and skimmings (zinc content) | | Zinc fume (zinc content) | | Dust, powder, flakes | | Total value[2] (thousands) |
|---|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | |
| 1983 | 6,508 | $3,314 | 631 | $420 | 6,533 | $7,126 | $533,396 |
| 1984 | 5,027 | 3,161 | 314 | 171 | 7,572 | 9,505 | 683,211 |
| 1985 | 4,942 | 2,419 | -- | -- | 8,681 | 10,781 | 559,434 |

[1] Unwrought alloys of zinc were imported as follows, in metric tons: 1983—49 ($84,907); 1984—118 ($100,047); and 1985—1,096 ($841,413).

[2] In addition, the value of manufactures of zinc imported was as follows: 1983—$542,571; 1984—$926,981; and 1985—$713,112.

Source: Bureau of the Census.

## Table 33.—U.S. imports for consumption of zinc pigments and compounds

| | 1984 | | 1985 | |
|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Zinc oxide | 35,741 | $35,516 | 39,375 | $35,122 |
| Zinc sulfide | 982 | 1,455 | 672 | 1,057 |
| Lithopone | 1,455 | 793 | 1,108 | 630 |
| Zinc chloride | 1,226 | 855 | 2,385 | 1,668 |
| Zinc sulfate | 2,855 | 1,574 | 3,615 | 2,049 |
| Zinc cyanide | 150 | 304 | 160 | 254 |
| Zinc hydrosulfite | 288 | 477 | 142 | 227 |
| Zinc compounds, n.s.p.f. | 9,735 | 7,204 | 4,858 | 7,267 |

Source: Bureau of the Census.

## Table 34.—Zinc: World mine production (content of concentrate and direct shipping ore unless noted), by country[1]

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984$^{p}$ | 1985$^{e}$ |
|---|---|---|---|---|---|
| Algeria | $^{r}$10.7 | $^{r}$11.1 | 12.1 | 14.6 | 12.0 |
| Argentina | $^{r}$35.2 | 36.4 | 36.6 | 35.9 | 36.0 |
| Australia | 518.3 | 664.8 | 699.0 | 659.1 | $^{p}$734.0 |
| Austria | 18.2 | 19.1 | 19.4 | 20.9 | 21.5 |
| Bolivia | 47.0 | 45.7 | 47.1 | 37.8 | 41.0 |
| Brazil | $^{r}$95.2 | $^{r}$110.6 | 118.6 | 103.2 | 110.0 |
| Bulgaria$^{e}$ | 65.0 | 66.0 | 68.0 | 68.0 | 68.0 |
| Burma | 3.6 | 5.4 | 4.5 | 5.3 | $^{2}$4.4 |
| Canada | 1,096.0 | 1,036.1 | 1,069.7 | 1,207.1 | 1,175.0 |
| Chile | 1.5 | 5.7 | 6.0 | 19.2 | 18.0 |
| China$^{e}$ | 160.0 | 160.0 | 160.0 | 160.0 | 190.0 |
| Colombia | .3 | -- | -- | -- | 1.0 |
| Congo (Brazzaville)$^{e}$ | 3.0 | 3.0 | 3.0 | $^{r}$2.8 | 3.0 |
| Czechoslovakia | $^{r}$9.2 | $^{r}$9.3 | 9.8 | 7.2 | 7.3 |
| Ecuador | .7 | $^{r}$($^{3}$) | ($^{3}$) | $^{e}$.1 | .1 |
| Finland | 53.5 | 54.6 | 55.9 | 60.2 | 61.6 |
| France | 37.4 | 37.0 | 34.3 | 36.2 | $^{p}$39.9 |
| Germany, Federal Republic of | 110.7 | 105.8 | 113.5 | 113.0 | 117.5 |
| Greece | 27.0 | 20.4 | 21.3 | $^{e}$21.5 | 22.0 |
| Greenland | 79.7 | 80.0 | 73.1 | 71.3 | $^{p}$79.4 |
| Guatemala | 3.0 | 1.0 | -- | -- | -- |
| Honduras | 16.2 | 24.6 | 38.0 | 41.5 | $^{2}$44.0 |
| Hungary$^{e}$ | 1.3 | 1.5 | 2.4 | 2.3 | 2.2 |

See footnotes at end of table.

### Table 34.—Zinc: World mine production (content of concentrate and direct shipping ore unless noted), by country[1] —Continued

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| India | 29.1 | 29.1 | 40.4 | 44.3 | [2]44.3 |
| Iran | [e]35.0 | [e]40.0 | 30.0 | 30.0 | 36.0 |
| Ireland | 120.3 | 167.2 | 186.0 | 206.1 | 192.0 |
| Italy | 43.9 | 39.6 | 42.9 | 42.3 | [2]45.4 |
| Japan | 242.0 | 251.4 | 255.7 | 252.7 | [2]252.0 |
| Korea, North[e] | 140.0 | 140.0 | 140.0 | 140.0 | 160.0 |
| Korea, Republic of | 56.2 | 58.2 | 56.0 | 49.2 | 44.8 |
| Mexico | 206.6 | 242.3 | 266.3 | 303.6 | 280.0 |
| Morocco[e] | [r]7.2 | 11.2 | [r]7.5 | [r]10.9 | 13.6 |
| Namibia | 29.6 | [e]32.2 | 33.5 | 32.2 | [2]29.7 |
| Nigeria[e] | .1 | .1 | .1 | .1 | .1 |
| Norway | 28.5 | 31.8 | 32.3 | 28.7 | [2]27.8 |
| Peru | 498.9 | 507.1 | 576.4 | 558.5 | [2]588.6 |
| Philippines | 5.3 | 3.0 | 2.3 | 2.2 | [2]1.9 |
| Poland | [r]201.5 | [r]183.5 | 189.0 | 190.7 | 187.0 |
| Romania[e] | 50.0 | 45.0 | 45.0 | 44.0 | 43.0 |
| South Africa, Republic of | 87.2 | 91.5 | 110.0 | 106.1 | [2]96.9 |
| Spain | 182.0 | 167.0 | 167.7 | 230.4 | [2]227.8 |
| Sweden | 180.9 | 185.0 | 202.9 | 205.9 | [2]206.8 |
| Thailand | -- | -- | -- | 41.4 | 77.5 |
| Tunisia | [r]8.2 | [r]8.4 | 7.5 | 6.7 | 5.5 |
| Turkey | [r]30.8 | [r]33.5 | 31.1 | 50.7 | 50.4 |
| U.S.S.R.[e] | 790.0 | 800.0 | 805.0 | 810.0 | 810.0 |
| United Kingdom | 10.9 | 10.2 | 8.9 | 7.5 | [2]5.4 |
| United States | 343.0 | 326.5 | 296.7 | 277.5 | [2]251.9 |
| Vietnam[e] | [r]6.5 | 6.0 | 7.0 | 7.0 | 5.0 |
| Yugoslavia[4] | 88.6 | 83.8 | 86.8 | 82.0 | 84.0 |
| Zaire | 63.3 | 82.1 | 76.2 | 74.8 | 74.0 |
| Zambia | [r]40.6 | [r]52.0 | 55.2 | 41.1 | 36.0 |
| **Total** | **[r]5,918.9** | **[r]6,125.8** | **6,350.7** | **6,563.8** | **6,656.0** |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Table includes data available through July 15, 1986.

[2]Reported figure.

[3]Less than 1/2 unit.

[4]Content in ore hoisted.

### Table 35.—Zinc: World smelter production, by country[1]

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria, primary | [r]27.0 | [r]28.5 | 31.2 | 35.0 | 31.2 |
| Argentina, primary | 26.8 | 28.9 | 32.0 | 31.0 | 31.0 |
| Australia: | | | | | |
| Primary[2] | 295.9 | 291.4 | 298.5 | 301.9 | 288.4 |
| Secondary[e] | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 |
| Total[e] | 300.4 | 295.9 | 303.0 | [r]306.4 | 292.9 |
| Austria, primary and secondary | 22.7 | 23.0 | 23.0 | 24.0 | 25.0 |
| Belgium, primary and secondary | 234.7 | 228.3 | 262.6 | 270.7 | 277.0 |
| Brazil: | | | | | |
| Primary | 91.9 | 95.5 | 99.9 | 106.9 | 110.0 |
| Secondary | 19.0 | 14.4 | 11.0 | 7.5 | 10.0 |
| Total | 110.9 | 109.9 | 110.9 | 114.4 | 120.0 |
| Bulgaria, primary and secondary[e] | 90.0 | 90.0 | 90.0 | 90.0 | 90.0 |
| Canada, primary | [r]618.6 | [r]511.9 | 617.0 | 683.2 | [3]692.4 |
| China, primary and secondary[e] | 160.0 | 160.0 | 175.0 | 185.0 | 190.0 |
| Czechoslovakia, undifferentiated | 9.0 | 9.2 | [r][e]9.1 | [r][e]9.1 | 9.2 |
| Finland, primary | 139.8 | [r]155.0 | 155.3 | 158.8 | [3]160.4 |
| France: | | | | | |
| Primary[e] | 232.1 | 223.8 | [r]231.5 | 238.8 | 230.0 |
| Secondary[e] | 25.0 | 20.0 | 18.0 | 20.0 | 17.0 |
| Total | 257.1 | 248.8 | 249.5 | 258.8 | [3]247.0 |
| German Democratic Republic, primary and secondary[e] | 16.0 | 17.0 | 16.5 | 17.0 | 16.0 |

See footnotes at end of table.

### Table 35.—Zinc: World smelter production, by country[1] —Continued

(Thousand metric tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Germany, Federal Republic of: | | | | | |
| Primary | 331.5 | 303.4 | 328.7 | 325.6 | [3]339.9 |
| Secondary | 35.1 | 31.6 | 27.8 | 30.8 | [3]27.9 |
| Total | 366.6 | 335.0 | 356.5 | 356.4 | [3]367.8 |
| Greece, secondary | .4 | NA | NA | NA | NA |
| Hungary, secondary[e] | .6 | .6 | .6 | .6 | .6 |
| India: | | | | | |
| Primary | 57.4 | 52.6 | 58.3 | 55.8 | [3]70.9 |
| Secondary[e] | .2 | .2 | .2 | .2 | .2 |
| Total | 57.6 | 52.8 | 58.5 | 56.0 | 71.1 |
| Italy, primary and secondary | 180.9 | [r]158.6 | 155.9 | 169.7 | [3]215.6 |
| Japan: | | | | | |
| Primary | 575.6 | 549.0 | 579.0 | 644.4 | [3]630.0 |
| Secondary | 94.6 | 113.4 | 122.8 | 110.1 | [3]110.0 |
| Total | 670.2 | 662.4 | 701.8 | 754.5 | [3]740.0 |
| Korea, North, primary[e] | 120.0 | 120.0 | 120.0 | 120.0 | 140.0 |
| Korea, Republic of, primary | 83.9 | 99.2 | 108.0 | 108.5 | 111.7 |
| Mexico, primary | 126.5 | 127.0 | 175.7 | 167.9 | 170.0 |
| Netherlands, primary and secondary | 177.4 | 186.0 | 187.5 | 209.7 | 202.3 |
| Norway, primary | 80.3 | 79.0 | 90.7 | 94.2 | [3]92.7 |
| Peru, primary | 126.2 | 160.7 | 154.0 | 149.0 | [3]162.3 |
| Poland, primary and secondary | 167.1 | 165.4 | 170.8 | 176.0 | [3]162.3 |
| Portugal, primary | 4.6 | [r]4.2 | 3.8 | 6.4 | 6.0 |
| Romania, primary and secondary[e] | [3]45.2 | [r]39.8 | 42.0 | 41.9 | 40.0 |
| South Africa, Republic of, primary | 87.2 | 79.7 | 84.4 | 88.4 | [3]90.3 |
| Spain, primary | 179.5 | 181.8 | 189.9 | 207.4 | [3]205.3 |
| Thailand, primary | -- | -- | -- | ([4]) | 62.1 |
| Turkey, primary | 18.1 | 14.9 | 14.8 | 19.5 | 12.0 |
| U.S.S.R.:[e] | | | | | |
| Primary | 820.0 | 830.0 | 835.0 | 850.0 | 860.0 |
| Secondary | 85.0 | 90.0 | 95.0 | 95.0 | 100.0 |
| Total | 905.0 | 920.0 | 930.0 | 945.0 | 960.0 |
| United Kingdom, primary and secondary | [r]81.6 | 79.3 | 87.7 | 85.6 | [3]74.3 |
| United States: | | | | | |
| Primary | 346.6 | 228.2 | 235.7 | 253.1 | [3]236.0 |
| Secondary | 50.2 | 74.3 | 60.4 | 78.1 | [3]75.6 |
| Total | 396.8 | 302.5 | 305.1 | 331.2 | [3]311.6 |
| Vietnam, primary[e] | [r]5.0 | 5.0 | 6.0 | 6.0 | 4.2 |
| Yugoslavia: | | | | | |
| Primary[e] | 86.4 | 76.8 | [r]77.0 | 81.6 | 71.4 |
| Secondary[e] | 10.0 | 10.0 | 11.0 | 11.0 | 12.0 |
| Total | 96.4 | 86.8 | 88.0 | 92.6 | [3]83.4 |
| Zaire, primary | 57.6 | 64.4 | 62.5 | 66.1 | 67.9 |
| Zambia, primary | 33.8 | 39.2 | 37.9 | 29.2 | 23.0 |
| Grand total | [r]6,081.0 | [r]5,865.7 | 6,200.7 | 6,463.4 | 6,566.5 |
| Of which: | | | | | |
| Primary | [r]4,571.8 | [r]4,350.1 | 4,621.3 | 4,827.3 | 4,889.1 |
| Secondary | [r]324.6 | 359.0 | 359.8 | 357.3 | 357.5 |
| Undifferentiated | [r]1,184.6 | [r]1,156.6 | 1,219.6 | 1,277.3 | 1,319.9 |

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1] Wherever possible, detailed information on raw material source of output (primary—directly from ores, and secondary—from scrap) has been provided. In cases where raw material source is unreported and insufficient data are available to estimate the distribution of the total, that total has been left undifferentiated (primary and secondary). To the extent possible, this table reflects metal production at the first measurable stage of metal output. Table includes data available through July 15, 1986.

[2] Excludes zinc dust.

[3] Reported figure.

[4] Revised to zero.

# Zirconium and Hafnium[1]

### By W. Timothy Adams[2]

Zircon, the principal ore mineral of zirconium, was mined as a coproduct of ilmenite and rutile from sand deposits in Florida. Most zircon was used in the Eastern United States, with approximately 35% being used in foundry sands and the remainder in refractories, ceramics, abrasives, and in miscellaneous uses including the manufacture of chemicals and the production of zirconium metal and alloys. The value of zircon consumed was about $16 million. Hafnium was used in nuclear reactors, refractory alloys, and cutting-tool alloys.

**Table 1.—Salient U.S. zirconium statistics**

(Short tons)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Zircon: | | | | | |
| Production | W | W | W | W | W |
| Exports | 11,630 | 11,011 | 13,222 | 9,528 | 16,855 |
| Imports | 91,108 | 68,465 | 44,487 | 66,436 | 43,787 |
| Consumption[e] [1] | 150,000 | 93,000 | 100,000 | 130,000 | 130,000 |
| Stocks, yearend: Dealers and consumers[2] | 33,385 | [e]48,595 | [e]36,498 | [e]32,861 | [e]29,288 |
| Zirconium oxide: | | | | | |
| Production[3] | 8,251 | 5,059 | [e]4,118 | [e]7,373 | [e]9,173 |
| Exports | 782 | 1,017 | 698 | 422 | 1,048 |
| Imports | 235 | 332 | 451 | 793 | 1,468 |
| Consumption[e] | 8,600 | 5,600 | 3,400 | 5,800 | 7,500 |
| Stocks, yearend: Producers[3] | 1,483 | 1,357 | [e]895 | [e]1,183 | [e]1,524 |

[e] Estimated. W Withheld to avoid disclosing company proprietary data.
[1] Includes insignificant amounts of baddeleyite.
[2] Excludes foundries.
[3] Excludes oxide produced by zirconium metal producers.

**Domestic Data Coverage.**—Domestic mine production data for zircon are developed by the Bureau of Mines from one voluntary survey of U.S. operations entitled "Production of Zircon." Of the two operations to which a survey request was sent, both responded, representing 100% of production. Data are withheld to avoid disclosing company proprietary data.

**Legislation and Government Programs.**—As part of a longstanding program to supply contractors with nuclear reactor construction material manufactured to U.S. Navy specifications, the U.S. Department of Energy had an inventory, as of December 31, 1985, of about 39 short tons of zirconium sponge, 1,000 tons of zirconium ingots and shapes, 2 tons of zirconium scrap, 31 tons of hafnium ingots and shapes, 3 tons of hafnium crystal bar, 5 tons of hafnium oxide, and 1 ton of hafnium scrap.

## DOMESTIC PRODUCTION

Zircon was recovered, along with titanium minerals, by E. I. du Pont de Nemours & Co. Inc. at Starke and Trail Ridge, FL, and by Associated Minerals (USA) Ltd. Inc. at Green Cove Springs, FL. The combined zircon capacity of these plants was estimated to be 125,000 tons per year. Production data were withheld from publication to avoid disclosing company proprietary data.

Five firms produced 47,117 tons of milled (ground) zircon from domestic and imported zircon, and six companies, excluding those that produce the oxide as an intermediate product in making zirconium sponge metal, produced 9,173 tons of zirconium dioxide. Two companies produced zirconium sponge, ingot, and alloys, as well as hafnium sponge and crystal bar.

### Table 2.—Producers of zirconium and hafnium materials in 1985

| Company | Location | Materials |
|---|---|---|
| ZIRCONIUM MATERIALS | | |
| American Minerals | Camden, NJ | Milled zircon. |
| Associated Minerals (USA) Ltd. Inc | Green Cove Springs, FL | Zircon. |
| Carborundum Co | Falconer, NY | Refractories. |
| Ciba-Geigy Corp., Drakenfeld Colors | Washington, PA | Ceramic colors and milled. |
| Continental Mineral Processing Corp | Sharonville, OH | Milled zircon. |
| Corhart Refractories Corp | Louisville, KY | Refractories. |
| Do | Corning, NY | Do. |
| Do | Buckhannon, WV | Do. |
| Didier-Taylor Refractories Corp | South Shore, KY | Do. |
| Do | Cincinnati, OH | Do. |
| E. I. du Pont de Nemours & Co. Inc | Starke and Trail Ridge, FL | Zircon and foundry mixes. |
| Elkem Metals Co | Alloy, WV | Alloys. |
| Foote Mineral Co | Cambridge, OH | Do. |
| A. P. Green Refractories Co., Remmey Div | Philadelphia, PA | Refractories. |
| Harbison-Walker Refractories | Mount Union, PA | Do. |
| Harshaw Chemical Co | Elyria, OH | Oxide and other compounds. |
| Leco Corp., Ceramics Div | St. Joseph, MI | Refractories and milled zircon. |
| Lincoln Electric Co. Inc | Cleveland, OH | Welding rods. |
| M & T Chemicals Inc | Andrews, SC | Ultrox and milled zircon. |
| Magnesium Elektron Inc | Flemington, NJ | Compounds. |
| Norton Co | Huntsville, AL | Oxide. |
| Reading Alloys | Robesonia, PA | Alloys. |
| Shieldalloy Corp | Newfield, NJ | Welding rods and alloys. |
| Sola Basic Industries, Engineered Ceramics Div | Gilberts, IL | Ceramics. |
| TAM Ceramics | Niagara Falls, NY | Milled zircon, oxide, compounds. |
| Teledyne Wah Chang Albany | Albany, OR | Oxide, sponge, ingot, mill products. |
| Thiokol Corp., Ventron Chemicals Div | Beverly, MA | Oxide. |
| Transelco, a division of Ferro Corp | Bow, NH | Do. |
| Western Zirconium Inc | Ogden, UT | Oxide, sponge, ingot, mill products. |
| Zedmark Inc | Butler, PA | Refractories. |
| Zircar Products Inc | Florida, NY | Fibrous ceramics. |
| ZIRCOA Products, Ceramic Products | Solon, OH | Oxide and ceramics. |
| HAFNIUM MATERIALS | | |
| Teledyne Wah Chang Albany | Albany, OR | Oxide, sponge, ingot, crystal bar. |
| Western Zirconium Inc | Ogden, UT | Do. |

## CONSUMPTION AND USES

About 35% of the domestic zircon produced in 1985 was used in proprietary mixtures as foundry sand, and the remainder was used in refractory sand blends with kyanite, sillimanite, and staurolite; in chemicals; in weighting agents; in glazes and enamels; in refractories; in ceramics; in zircon-titanium dioxide blends for welding-rod coatings; for sandblasting applications; and for the production of zirconium and hafnium metals. Baddeleyite, another zirconium mineral, was used mainly in the manufacture of alumina-zirconia abrasives, and also for ceramic colors, refractories, and other uses.

### Table 3.—Estimated[1] consumption of zircon[2] in the United States, by end use

(Short tons)

| End use | 1984 | 1985 |
|---|---|---|
| Zircon refractories[3] | 24,500 | 28,200 |
| AZS refractories[4] | 8,200 | 4,300 |
| Zirconia[5] and AZ abrasives[6] | 15,300 | 20,600 |
| Alloys[7] | 4,400 | 4,700 |
| Foundry applications | 49,500 | 45,500 |
| Other[8] | 28,100 | 26,700 |
| Total | 130,000 | 130,000 |

[1] Based on incomplete reported data.

[2] Includes insignificant amounts of baddeleyite.

[3] Dense and pressed zircon brick and shapes.

[4] Fused cast and bonded alumina-zirconia-silica-based refractories.

[5] Excludes oxide produced by zirconium metal producers.

[6] Alumina-zirconia-based abrasives.

[7] Excludes alloys above 90% zirconium.

[8] Includes chemicals, metallurgical-grade zirconium tetrachloride, sandblasting, welding rods, and miscellaneous uses.

Research on calcia, magnesia, and yttria transformation-toughened zirconias continued. These materials were considered to have considerable potential for use in ceramic coatings in jet aircraft engines and in other applications where strength and high-temperature oxidation resistance is important. Zirconia ceramics were also used in the automobile industry in sensors for the microprocessor controls on engines.

All of the hafnium metal and most of the zirconium metal consumed were used by the nuclear power industry. For the seventh consecutive year, there were no new orders for commercial nuclear powerplants. However, for the first time in 10 years, no commercial nuclear powerplant was canceled. Most of the remainder of the zirconium metal was used in superalloys and in the chemical and electronics industries.

### Table 4.—Estimated[1] consumption of zirconium oxide[2] in the United States, by end use

(Short tons)

| End use | 1984 | 1985 |
|---|---|---|
| AZ abrasives | W | W |
| AZS refractories[3] | 900 | 300 |
| Other refractories | 2,900 | 4,300 |
| Chemicals | 700 | 1,300 |
| Glazes, opacifiers, colors | 1,300 | 1,600 |
| Total | 5,800 | 7,500 |

W Withheld to avoid disclosing company proprietary data.

[1] Based on incomplete data.

[2] Excludes oxide produced by zirconium metal producers. Includes baddeleyite.

[3] Fused cast and bonded.

### Table 5.—Estimated[1] yearend stocks of zirconium and hafnium materials in the United States

(Short tons)

| Item | 1984 | 1985 |
|---|---|---|
| Zircon concentrate held by dealers and consumers excluding foundries | 25,653 | 20,240 |
| Milled zircon held by dealers and consumers excluding foundries | 7,208 | 9,048 |
| Zirconium:[2] | | |
| Oxide | 1,183 | 1,524 |
| Sponge, ingot, scrap, alloys | 785 | 924 |
| Refractories | 17,281 | 6,673 |
| Hafnium: Sponge and crystal bar | 30 | 30 |

[1] Based on incomplete data.

[2] Excludes material held by zirconium sponge metal producers.

## Table 6.—Published prices of Australian zircon

(U.S. dollars per ton)

| Date of publication | Standard grade | Intermediate grade | Premium grade |
|---|---|---|---|
| December 1984 | 83-90 | 86- 94 | 96-101 |
| December 1985 | 77-83 | 99-108 | 102-108 |

Source: Industrial Minerals (London). No. 207, Dec. 1984, p. 78; and No. 219, Dec. 1985, p. 101.

## Table 7.—Published yearend prices of zirconium and hafnium materials

| Specification of material | 1984 | 1985 |
|---|---|---|
| Zircon: | | |
| Domestic, standard grade, f.o.b. Starke, FL, bulk, per short ton[1] | $165.00 | $175.00 |
| Domestic, 75% minimum quantity zircon and aluminum silicates, Starke, FL, bulk, per short ton[1] | 99.00 | 99.00 |
| Imported sand, containing 65% $ZrO_2$, f.o.b., bulk, per metric ton[2] | $91.00- 99.00 | $86.00- 92.00 |
| Domestic, granular, bags, bulk rail, from works, per short ton[3] | 165.00- 177.00 | 165.00- 177.00 |
| Domestic, milled, 200- and 325-mesh, rail, from works, bags, per short ton[3] | 225.00 | 225.00 |
| Baddeleyite, imported concentrate:[4] | | |
| 96% to 98% $ZrO_2$, minus 100-mesh, c.i.f. Atlantic ports, per pound | .50 | .50 |
| 99 + % $ZrO_2$, minus 325-mesh, c.i.f. Atlantic ports, per pound | .97 | .97 |
| Zirconium oxide:[3] | | |
| Powder, commercial grade, drums, 2,000-pound minimum, per pound | 4.25 | 4.25 |
| Electronic, same basis, per pound | 7.25 | 7.25 |
| Insulating, stabilized, 325° F, same basis, per pound | 3.31- 3.82 | 3.31- 3.82 |
| Insulating, unstabilized, 325° F, same basis, per pound | 3.55- 3.75 | 3.55- 3.75 |
| Dense, stabilized, 30° F, same basis, per pound | 2.82 | 2.82 |
| Zirconium oxychloride: Crystal, cartons, 5-ton lots, from works, per pound[3] | .91- 1.04 | .91- 1.04 |
| Zirconium acetate solution:[3] | | |
| 25% $ZrO_2$, drums, carlots, 15-ton minimum, from works, per pound | .97 | .97 |
| 22% $ZrO_2$, same basis, per pound | .78 | .78 |
| Zirconium hydride: Electronic grade, powder, drums, 100-pound lots, from works, per pound[3] | 31.75 | 31.75 |
| Zirconium:[5] | | |
| Powder, per pound | 75.00- 150.00 | 75.00- 150.00 |
| Sponge, per pound | 12.00- 17.00 | 12.00- 17.00 |
| Sheets, strip, bars, per pound | 20.00- 40.00 | 20.00- 40.00 |
| Hafnium: Sponge, per pound[5] | 80.00- 130.00 | 80.00- 130.00 |

[1] E. I. du Pont de Nemours & Co. Inc. price list Dec. 1984 (effective Jan. 1, 1985); and Dec. 1985 (effective Jan. 1, 1986).

[2] Industrial Minerals (London). No. 207, Dec. 1984, p. 78; and No. 219, Dec. 1985, p. 101.

[3] Chemical Marketing Reporter. V. 226, No. 27, Dec. 31, 1984 (effective Dec. 28, 1984), p. 28; and v. 228, No. 27, Dec. 30, 1985 (effective Dec. 27, 1985), p. 32.

[4] Ronson Metals Corp. Baddeleyite price lists. Jan. 1, 1985, and Jan. 1, 1986.

[5] American Metal Market. V. 92, No. 250, Dec. 28, 1984, p. 7; and v. 93, No. 249, Dec. 27, 1985, p. 5.

## Table 8.—U.S. exports of zirconium ore and concentrate, by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Short tons | Value | Short tons | Value |
| Algeria | 56 | $28,050 | 56 | $28,050 |
| Argentina | 523 | 184,361 | 370 | 102,218 |
| Belgium-Luxembourg | -- | -- | 80 | 51,736 |
| Brazil | -- | -- | 3,601 | 557,658 |
| Canada | 391 | 128,552 | 249 | 72,675 |
| Colombia | 487 | 247,990 | 291 | 115,725 |
| Ecuador | 147 | 79,922 | 104 | 65,036 |
| Germany, Federal Republic of | 2,197 | 827,562 | 2,194 | 752,909 |
| India | 15 | 10,883 | 10 | 5,850 |
| Japan | 3,643 | 389,940 | 3,578 | 493,252 |
| Mexico | 1,105 | 302,334 | 5,391 | 1,242,625 |
| United Kingdom | 38 | 5,239 | 38 | 9,752 |
| Venezuela | 762 | 352,029 | 662 | 344,829 |
| Other | 164 | 89,717 | 231 | 123,179 |
| Total | 9,528 | 2,646,579 | 16,855 | 3,965,461 |

Source: Bureau of the Census.

## Table 9.—U.S. exports of zirconium, by class and country

| Class and country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Short tons | Value | Short tons | Value |
| **Zirconium and zirconium alloys, wrought:** |  |  |  |  |
| Belgium-Luxembourg | 47 | $3,854,895 | 12 | $918,662 |
| Canada | 181 | 10,566,721 | 184 | 9,658,049 |
| France | 12 | 291,188 | 1 | 45,012 |
| Germany, Federal Republic of | 88 | 5,240,786 | 107 | 5,782,189 |
| Italy | 2 | 48,188 | 31 | 2,644,304 |
| Japan | 259 | 12,418,815 | 473 | 20,938,200 |
| Korea, Republic of | 9 | 411,756 | 1 | 55,851 |
| Spain | (1) | 12,644 | 7 | 52,948 |
| Sweden | 13 | 400,851 | 37 | 1,434,725 |
| Switzerland | 1 | 76,488 | 4 | 385,578 |
| Taiwan | (1) | 39,657 | 17 | 1,405,102 |
| United Kingdom | 33 | 1,299,754 | 53 | 2,232,026 |
| Other | 3 | 150,928 | 3 | 120,091 |
| Total | 648 | 34,812,671 | 930 | 45,672,737 |
| **Zirconium and zirconium alloys, unwrought and waste and scrap:** |  |  |  |  |
| Chile | 20 | 693,440 | 12 | 380,000 |
| France | (1) | 5,667 | 48 | 491,293 |
| Germany, Federal Republic of | 9 | 74,364 | 18 | 375,887 |
| Japan | 108 | 6,704,625 | 122 | 4,086,304 |
| Netherlands | 3 | 13,038 | 1 | 9,110 |
| Peru | -- | -- | 16 | 328,000 |
| United Kingdom | 17 | 116,019 | 1 | 80,776 |
| Other | 3 | 102,928 | 5 | 133,751 |
| Total | 160 | 7,710,081 | 223 | 5,885,121 |

[1] Less than 1/2 unit.

Source: Bureau of the Census.

## Table 10.—U.S. exports of zirconium oxide, by country

| Country | 1984 |  | 1985 |  |
|---|---|---|---|---|
|  | Short tons | Value | Short tons | Value |
| Argentina | 18 | $56,261 | -- | -- |
| Belgium-Luxembourg | 16 | 22,222 | 18 | $25,106 |
| Brazil | 19 | 66,491 | 20 | 777,387 |
| Canada | 52 | 182,928 | 157 | 516,629 |
| France | 13 | 46,313 | 31 | 109,597 |
| Germany, Federal Republic of | 19 | 82,222 | 9 | 58,966 |
| Greece | -- | -- | 5 | 6,400 |
| Hong Kong | 5 | 10,491 | 5 | 10,886 |
| Italy | 37 | 115,801 | 38 | 114,279 |
| Japan | 62 | 192,127 | 45 | 162,614 |
| Korea, Republic of | -- | -- | 315 | 125,819 |
| Mexico | 47 | 113,212 | 93 | 287,644 |
| Netherlands | 11 | 31,923 | 2 | 10,506 |
| Sweden | 16 | 65,241 | 2 | 38,276 |
| Taiwan | 17 | 54,974 | 19 | 66,965 |
| United Kingdom | 70 | 131,532 | 281 | 942,148 |
| Other | 20 | 91,025 | 8 | 78,693 |
| Total | 422 | 1,262,763 | 1,048 | 3,331,915 |

Source: Bureau of the Census.

## Table 11.—U.S. imports for consumption of zirconium ores, by country

| Country | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) | Quantity (short tons) | Value (thousands) |
| Argentina | -- | -- | -- | -- | 5,799 | $520 |
| Australia | 36,140 | $3,385 | 44,214 | $5,289 | 24,348 | 2,272 |
| Austria[1] | 118 | 13 | -- | -- | -- | -- |
| Belgium-Luxembourg | -- | -- | 461 | 87 | -- | -- |
| Canada[1] | 1,176 | 122 | 1,451 | 151 | 2,307 | 225 |
| Hong Kong | -- | -- | -- | -- | 333 | 28 |
| Italy | -- | -- | -- | -- | 64 | 25 |
| Philippines | -- | -- | -- | -- | 87 | 407 |
| South Africa, Republic of[2] | 7,053 | 897 | 20,309 | 2,016 | 10,849 | 1,120 |
| Other | ([3]) | 3 | 1 | 5 | ([3]) | 2 |
| Total | 44,487 | 4,420 | 66,436 | 7,548 | 43,787 | 4,599 |

[1] Believed to be country of shipment rather than country of origin.
[2] In addition, very small quantities of baddeleyite were imported.
[3] Less than 1/2 unit.

Source: Bureau of the Census.

## Table 12.—U.S. imports for consumption of zirconium and hafnium in 1985, by class and country

| Class and country | Short tons | Value |
|---|---|---|
| Zirconium, wrought: |  |  |
| Canada | 2 | $64,709 |
| France | 340 | 17,504,003 |
| Japan | 3 | 43,410 |
| Other | ([1]) | 12,271 |
| Total | [2]346 | 17,624,393 |
| Zirconium, unwrought and waste and scrap: |  |  |
| Belgium-Luxembourg | 9 | 79,570 |
| Canada | 28 | 61,630 |
| France | 6 | 98,121 |
| Japan | 9 | 60,095 |
| Netherlands | 9 | 80,898 |
| United Kingdom | 33 | 199,399 |
| Total | 94 | 579,713 |
| Zirconium alloys, unwrought: |  |  |
| Belgium-Luxembourg | 1 | 7,364 |
| Germany, Federal Republic of | 5 | 141,610 |
| United Kingdom | 5 | 37,808 |
| Total | [2]10 | 186,782 |
| Zirconium oxide: |  |  |
| France | 145 | 287,870 |
| Germany, Federal Republic of | 1 | 39,352 |
| Japan | 110 | 304,304 |
| Netherlands | 2 | 3,530 |
| South Africa, Republic of | 750 | 431,562 |
| United Kingdom | 460 | 2,516,725 |
| Total | 1,468 | 3,585,333 |
| Zirconium compounds: |  |  |
| Australia | 19 | 3,072 |
| Belgium-Luxembourg | 17 | 50,401 |
| France | 30 | 95,197 |
| Germany, Federal Republic of | 6 | 274,378 |
| Greece | 40 | 71,101 |
| Japan | 177 | 125,632 |
| South Africa, Republic of | 1,370 | 1,226,312 |
| United Kingdom | 624 | 1,133,646 |
| Other | 1 | 6,109 |
| Total | 2,284 | 2,985,848 |

See footnotes at end of table.

**Table 12.—U.S. imports for consumption of zirconium and hafnium in 1985, by class and country —Continued**

| Class and country | Short tons | Value |
|---|---|---|
| Hafnium, unwrought and waste and scrap: | | |
| France | 1 | $179,613 |
| United Kingdom | (1) | 5,654 |
| Total | 1 | 185,267 |

[1] Less than 1/2 unit.

[2] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

## WORLD REVIEW

Australia led the world in the production of zircon in 1985. Zircon was also produced in the Republic of South Africa, the U.S.S.R., and the United States, and in lesser amounts in six other countries. Baddeleyite was produced in Brazil and in the Republic of South Africa.

**Australia.**—The Commonwealth Scientific and Industrial Research Organization (CSIRO) and ICI Australia collaborative research effort developed a suitable manufacturing process for the production of zirconia in Australia. Process trials conducted in the second half of 1985 showed the feasibility of producing a wide range of high-value zirconia ceramic powders and zirconium chemicals for domestic use and export to world markets. CSIRO and ICI Australia formed Z-Tech, a joint venture company, on October 29, 1985, to manufacture these materials from Australian zircon. A plant, with a capacity of 2,000 tons per year, was scheduled to be constructed at Kwinana, Western Australia, and completed in 1987.[3]

Renison Goldfields Pty. Ltd., owned by Consolidated Goldfields Pty. Ltd., acquired Du Pont's 50% interest in Allied Eneabba Pty. Ltd., which has holdings in Western Australia. Consolidated Goldfields, a holding company, thus assumed a leading role in the mineral sands industry through this acquisition and through its Associated Minerals Consolidated Pty. Ltd. operation in Australia, as well as through Associated Minerals Consolidated (USA) Ltd. Inc. operations in Florida.[4]

**Brazil.**—A Brazilian mining company, Minegral-Cia. Brasileira de Mineração Industria e Comercio S.A., completed plans for the construction of a 1,100-ton-per-year zirconium dioxide plant. The oxide was to be produced from coldasite, a mineral that contains 60% zirconium dioxide. The mineral was to be concentrated to a 99% grade and the oxide produced from the concentrate. The concentration and oxide plants were scheduled to be built next to the mine at Poco de Caldas, in Minas Gerais State.[5]

**Gambia, The.**—The apparent firming of zircon prices induced the Government to reexamine heavy mineral reserves in the coastal areas of the country. Known heavy mineral reserves total 910,000 tons at 1% cutoff, of which 149,000 tons is zircon. It was proposed by the consultant that a small plant be erected to extract zircon from zircon-bearing waste material that had accumulated from earlier mining and recovery of titanium materials. The cash flow from sales of zircon was to be used to erect a larger heavy mineral extraction plant.[6]

**Germany, Federal Republic of.**—The State Authority for Geosciences of Niedersachsen (Lower Saxony State) concluded an extensive exploratory drilling program. An 11-million-ton deposit of heavy mineral sands was discovered near the Weser River close to the towns of Midlum and Hoisel. The deposit reportedly contains 1.1 million tons of zircon. Additional reserves west of the Weser River were indicated.[7]

**South Africa, Republic of.**—Richards Bay Minerals announced plans for the expansion in mining capacity for mineral sands in Natal. Production of zircon, estimated at 115,000 tons in 1985, was expected to increase to 160,000 tons in 1987.[8]

### Table 13.—Zirconium concentrate: World production, by country[1]

(Short tons)

| Country | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Australia | 478,673 | 509,792 | 421,419 | 501,037 | 485,000 |
| Brazil | 6,614 | 5,507 | 15,201 | 7,027 | 7,700 |
| China[e] | 16,500 | 16,500 | 16,500 | 16,500 | 16,500 |
| India[2] | 13,669 | 11,556 | 12,561 | [e]13,000 | 15,000 |
| Malaysia[3] | 1,441 | 2,367 | 2,809 | 8,393 | 9,900 |
| South Africa, Republic of | [e]110,000 | [e]140,000 | 178,884 | 168,789 | 220,500 |
| Sri Lanka | 3,600 | 6,381 | 6,306 | 4,087 | 4,080 |
| Thailand | 115 | 216 | 219 | 320 | 330 |
| U.S.S.R.[e] | 80,000 | 90,000 | 90,000 | 90,000 | 95,000 |
| United States | W | W | W | W | W |
| Total | 710,612 | [r]782,319 | 743,899 | 809,153 | 854,010 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Includes data available through May 20, 1986.

[2]Data are for fiscal year beginning Apr. 1 of that stated.

[3]The 1981-83 figures are exports, and the 1984-85 figures are production.

## TECHNOLOGY

A review of the market for two distinct raw materials—natural zirconia in the form of baddeleyite, and the higher purity manufactured zirconia, produced from zircon or in some cases from baddeleyite—was published. The reasons for the growth to date of markets for both materials were examined. The article gave a brief overview of zirconia markets and examined the possibility for growth, which is partly contingent on work still in the research stage.[9]

Work done at Sandia National Laboratories showed that failure of the yttria-stabilized thermal barrier coating on gas turbine blades can be caused by as little as 5 parts per million of sodium or 2 parts per million of vanadium, reducing the life of the blades by a factor of 100. The contaminants cause loss of yttria from the zirconia at operating temperature, leading to failure of the coating.[10]

Efforts to reduce signal attenuation in chemical-vapor-deposited zirconium fluoride glass fiber below 4 decibels per kilometer were unsuccessful. However, another manufacturing process, the double-crucible solid-state melting process, was used to produce a single-mode zirconium fluoride fiber of only 0.02 decibel per kilometer, significantly superior to the standard 0.16 decibel per kilometer silicon dioxide fiber presently used in the telecommunications industry.[11]

RMI Co., Niles, OH, announced acceptance of its zirconium-containing Bets-C titanium alloy for inclusion in the National Association of Corrosion Engineers Materials Requirement Standard for resistance to sulfide cracking in "sour" environments. The alloy contains 3.5% to 4.5% zirconium and is a heat-treatable, deep-hardenable alloy capable of ultimate strengths in excess of 200,000 pounds per square inch.[12]

Zirconia-based materials were used for precision casting molds to give highly accurate dimensions and smooth nonporous surfaces to cast titanium dental crowns. The titanium alloy, melted in a small electric arc furnace designed for use in a dental clinic, is cast in the precision zirconia mold in a vacuum, which prevents oxygen embrittlement and contamination.[13]

It was shown that hafnium hydroxide, precipitated by the addition of ammonium hydroxide to hafnium oxychloride solution, and calcined at 500° C, gives a catalyst capable of yielding isobutylene from synthesis gas with 98% yield at 400° C. Isobutylene is used to improve the octane rating of gasoline.[14]

Zirconium or hafnium additions to nickel aluminide were shown to extend potential commercial applications into diverse areas other than aerospace components. The new alloys were shown to have good ductility and extraordinary strength and oxidation resistance at high-temperature uses.[15]

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[1]Zirconium and hafnium are nearly identical in chemical properties and atomic volume and are associated in the principal ore mineral, zircon, in a ratio of about 50 to 1. The two elements are separated for nuclear power applications but not for other uses.

[2]Physical scientist, Division of Nonferrous Metals.

[3]Industrial Minerals (London). World of Minerals. Australia. Z-Tech Zirconia Plans. No. 219, Dec. 1985, p. 9.

[4]———. Comment. No. 219, Dec. 1985, p. 7

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[5] Engineering and Mining Journal. This Month in Mining: Brazil. V. 196, No. 11, Nov. 1985, p. 105.

[6] Industrial Minerals (London). A Proposal To Rejuvenate the Heavy Mineral Industry of The Gambia. No. 212, May 1985, p. 53.

[7] ———. The Industrial Minerals of West Germany. No. 219, Dec. 1985, p. 47.

[8] American Metal Market. RBM Plans Expansion for South Africa-Based Ilmenite Smelting Unit. V. 93, No. 138, July 19, 1985, pp. 5, 7.

[9] Dickson, E. M. Zirconia—Growth of a Specialty. Ind. Miner. (London), No. 209, Feb. 1985, pp. 49-53.

[10] Industrial Minerals (London). Sandia Research on Zirconia Coatings. No. 209, Feb. 1985, p. 16.

[11] Lasers and Applications. Fluoride Fiber Losses Reduced Further. V. 5, No. 2, Feb. 1985, pp. 36-37.

[12] American Metal Market. Alloying and Precious Metals. RMI's Beta-C Titanium Alloy Listed in NACE's Standards. V. 93, No. 64, Apr. 3, 1985, p. 6.

[13] ———. Dental Crowns of Titanium Under Study. V. 93, No. 154, Aug. 12, 1985, pp. 19-20.

[14] Chem Tech. Techgram Japan. Tokyo Institute of Technology. Research Laboratory of Resources Utilization, 4259, Nagatsuda-Machi, Midori-Ku, Yokahama 227 (0205 G2ON). V. 15, No. 9, Sept. 1985, p. 587.

[15] American Metal Market. Alloys and New Materials. New Applications Open Up for Nickel Aluminide. V. 95, No. 203, Oct. 21, 1985, pp. 17, 28.

# Other Industrial Minerals

### By Staff, Division of Industrial Minerals

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## ASPHALT (NATIVE)[1]

Native asphalt was produced by four companies in two States, Texas and Utah. Bituminous limestone, used primarily as a paving material for street and road repair, was produced by one firm, R. L. White Co., Dabney Quarry, Uvalde County, TX.

Gilsonite, a solidified hydrocarbon found only in Utah and Colorado, was mined by three firms: American Gilsonite Co., a division of Chevron Resources Co. (a subsidiary of Standard Oil Co. of California); Ziegler Chemical and Mineral Corp.; and Hydrocarbon Mining Co. (a subsidiary of Oberon Oil Inc., a Utah corporation), from properties in Uintah County, UT.

Gilsonite is used for a variety of purposes including automobile bodysealer, lightweight aggregate for cement used in oil well drilling, asphaltic building board, protective coverings, anticorrosive paints, and roofing compounds. Gilsonite production in 1985 declined 57% owing primarily to reduced oil well drilling activity. The value per ton was essentially unchanged.

Specific information on bituminous limestone and gilsonite production and value is withheld to avoid disclosing company proprietary data.

## GREENSAND[2]

Greensand, also known as glauconite, a natural silicate of potassium, aluminum, iron, and magnesium, was produced by Inversand Co., a subsidiary of Hungerford and Terry Inc., near Clayton, NJ, and by a new producer, Contractors Sand & Gravel Co., near Middletown, DE, who started production in the middle of May 1984. Production and sales information is withheld to avoid disclosing company proprietary data. Processed greensand continued to be sold as a filter media for the removal of manganese and iron from drinking water supply systems. Classified raw greensand was resold by Zook and Ranck Inc. as a soil conditioner and as a source of slowly released potash to organic farmers in North America.

## MEERSCHAUM[3]

Crude or block meerschaum was not imported during the year. Imports of crude or block meerschaum were last reported in 1983, all from the United Kingdom, totaling

1,543 pounds, with a customs declared value of $19,290. The high unit value of the 1983 imported material, $12.51 per pound, indicates that the shipments consisted of shaped or formed meerschaum blocks. The major suppliers in the past were the Federal Republic of Germany and Somalia.

Crude or block meerschaum continued to be mined in Turkey and recovered by artisans in Somalia and Tanzania. The block material was used by companies in New York and Ohio for manufacturing smokers' pipes and cigarette holders. Smokers' specialty houses complemented their finished meerschaum items with mail-order kits with detailed instructions for do-it-yourself carving of meerschaum smoking articles. Turkish production in 1985 was estimated to be over 300 unit boxes, 44 pounds each, of block meerschaum. Turkey, the largest producer of crude or block meerschaum, had prohibited exports of uncarved material since 1975.

## QUARTZ CRYSTAL[4]

Both U.S. mine production of lascas and consumption as feedstock for cultured quartz crystal output declined in 1985, owing to reduced domestic demand. Domestic cultured quartz crystal producers operated at less than 50% capacity. Imports of Brazilian lascas declined sharply, and exports of cultured quartz crystal were significantly lower than those of 1984.

**Domestic Data Coverage.**—Domestic production and consumption data for quartz crystal are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the seven operations canvassed for production of culturod quartz, all responded, and the six active operations represented 100% of total production shown in table 1. Of the 28 operations that consumed quartz crystal, all responded, and the 27 active operations represented 100% of total consumption also shown in table 1.

**Table 1.—Salient U.S. electronic- and optical-grade quartz crystal statistics**

(Thousand pounds and thousand dollars)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Production: | | | | | |
| Mine[e] [1] | 175 | 200 | 600 | 2,500 | 1,000 |
| Cultured | 660 | 478 | 426 | 1,027 | 568 |
| Exports: | | | | | |
| Natural:[2] | | | | | |
| Quantity | 127 | 69 | 28 | 42 | 60 |
| Value | $490 | $380 | $156 | $234 | $290 |
| Cultured:[2] | | | | | |
| Quantity | 125 | 115 | 80 | 277 | 185 |
| Value | $4,600 | $3,500 | $3,258 | $11,021 | $3,723 |
| Lascas:[3] | | | | | |
| Quantity | NA | NA | [3]339 | [e]1,600 | [e]800 |
| Imports of Brazilian lascas:[2] | | | | | |
| Quantity | 389 | 417 | 153 | 569 | 173 |
| Value | $233 | $245 | $121 | $373 | $99 |
| Consumption: | | | | | |
| Natural (electronic- and optical-grade) | 14 | 16 | 13 | 7 | 7 |
| Cultured (lumbered) | 282 | 99 | 112 | 77 | 44 |
| Cultured (as grown) | 327 | 383 | 312 | [r]391 | 224 |
| Total | 623 | 498 | 437 | [r]475 | 275 |

[e]Estimated. [r]Revised. NA Not available.

[1]Excludes lascas produced for specimen and jewelry material uses.

[2]Bureau of the Census.

[3]The Journal of Commerce Port Import/Export Reporting Service.

**Legislation and Government Programs.**—On July 8, the President approved National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict, which would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of material already possessed by the Government. Under this system, 265,000 pounds of natural quartz crystal would be placed in tier I, and 1.8 million pounds would be placed in tier II. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any reduction in a stockpile goal in effect on October 1, 1984.

At yearend 1985, the National Defense Stockpile total inventory was 1.8 million pounds of natural quartz crystal, with a goal of 600,000 pounds. Total sales of natural quartz crystal by the General Services Administration were 83,813 pounds.

## DOMESTIC PRODUCTION

Domestic mine production of lascas in 1985 was approximately 1 million pounds, all from Arkansas. The two producers were Geomex Mine Services Inc. and Coleman Crystal Inc. Coleman Crystal was the major supplier of lascas to the U.S. cultured quartz crystal industry. Primary output of Geomex was exported to the Federal Republic of Germany and Japan.

Domestic cultured quartz producers operated at reduced capacity, owing to increased lower-unit-cost production from Japan in the world market. Six companies produced cultured quartz crystal in the United States and output declined 45% from that of 1984. The two largest, Sawyer Research Products Inc., Eastlake, OH, and Thermo Dynamics Corp., Shawnee-Mission, KS, were independent growers that produced crystal bars for domestic and foreign consumers in the crystal device fabrication industry. Motorola Inc., Chicago, IL, produced for both internal consumption and the domestic fabrication industry. P. R. Hoffman Material Processing Co., Carlisle, PA, also reported outside sales during the year. AT&T Technologies Inc., North Andover, MA, was inactive. Bliley Electric Co., Erie, PA, and Electro Dynamics Corp., Shawnee-Mission, KS, produced only for internal consumption.

## CONSUMPTION AND USES

U.S. consumption of lascas by the six growers declined 60%, from 1.3 million pounds in 1984 to 522,000 pounds in 1985. Quartz crystal consumption by 27 companies in 10 States declined 42%, from 475,000 pounds (revised) in 1984 to 275,000 pounds in 1985. Of these companies, 22 consumed only cultured quartz crystal, 2 consumed only natural quartz crystal, and 3 consumed both natural and cultured material.

Imported natural quartz crystal continued to be required as seed material for growing cultured quartz. Cultured quartz crystal is the primary material used as resonators in electronic applications. Such applications include timing signals for watches and clocks; microprocessors in industrial, automotive, and consumer products; and military-aerospace and commercial band-pass filters and oscillators that require very high selectivity and stability.

## STOCKS

Reported industry stocks of cultured quartz crystal totaled approximately 138,000 pounds at the beginning of the year and increased to approximately 204,000 pounds by yearend.

## PRICES

The average reported value of lascas consumed for production of cultured quartz crystal was $0.57 per pound, the same as that reported in 1984. The average value of "as-grown" cultured quartz, based on reported sales of nearly 212,000 pounds, was $15.92 per pound, a decrease of 34% from that of 1984. The average value of lumbered quartz, as-grown quartz that has been processed by sawing and grinding, was $62.23 per pound, an increase of 13% from that of 1984, based upon 1985 sales of about 88,000 pounds.

## FOREIGN TRADE

Cultured quartz crystal exports, as reported by the Bureau of the Census, declined 33% to 185,000 pounds. Average value was $20.12 per pound. Japan received 114,000 pounds, and the Republic of Korea, 45,000 pounds. Most of the natural quartz crystal exports were bought from the National Defense Stockpile, primarily for nonpiezoelectric uses.

Imports of Brazilian lascas, designated "Crude Brazilian Pebble," declined 70% to 173,000 pounds.

## STAUROLITE[5]

Staurolite is a naturally occurring, complex, hydrated aluminosilicate of iron having a variable composition. The mineral most commonly occurs as opaque reddish-brown to black crystals with a specific gravity ranging from 3.74 to 3.83 and Mohs' hardness between 7 and 8.

A limited rock-shop trade in cruciform twinned staurolite crystals ("fairy crosses") exists, notably from deposits in Georgia, North Carolina, and Virginia. Staurolite in the United States was produced commercially in 1985 by E. I. duPont de Nemours & Co. Inc. and by Associated Minerals (U.S.A.) Ltd. Inc.

Staurolite is a byproduct of heavy mineral concentrates recovered from a glacial-age beach sand in Clay County, north-central Florida. The staurolite is removed by means of electrical and magnetic separation after the concentrates have been scrubbed and chemically washed with caustic, rinsed, and dried. The resulting fraction produced is comprised of about 77% clean, rounded, and uniformly sized grains of staurolite, with minor proportions of tourmaline, ilmenite and other titanium minerals, kyanite, zircon, and quartz. A nominal composition of this staurolite sand is 45% aluminum oxide (minimum), 18% ferric oxide (maximum), 5% titanium dioxide (maximum), and 5% silica.

Although originally marketed only as an ingredient in some portland cement formulations, staurolite is now marketed as a specialty sand under the trade name Biasill for use as a molding material in nonferrous foundries, owing to its low thermal expansion, high thermal conductivity, and high melting point. Its low softening point tends to restrict it to nonferrous casting. Its major use is as an abrasive for impact finishing of metals and sandblasting of buildings under the trade names Starblast (80 mesh) and Biasill (90 mesh), as well as a coarse grade (55 mesh) abrasive.

Quantitative production data are not released for publication, but the 1985 production of staurolite decreased 42% from that of 1984; shipments decreased 8% in tonnage and increased 12% in price per ton. Domestic productive capacity remained at about 135,000 short tons per year.

Staurolite has continued to be produced in India in small quantities and sometimes by other nations as well.

## STRONTIUM[6]

Imports of major strontium compounds for use in several downstream products increased, whereas imports of celestite, a strontium sulfate mineral, decreased because of consumer preference for the refined compounds. Strontium demand increased in several end uses requiring increased imports of strontium chromate, strontium nitrate, and precipitated and nonprecipitated strontium carbonate. The United States had been the leading producer of strontium compounds as late as 1982; however, only one U.S. producer, Chemical Products Corp. (CPC), remained in operation in 1985. Because celestite was not mined in the United States, CPC produced strontium carbonate from imported celestite.

**Domestic Data Coverage.**—Domestic production data for strontium are developed by the Bureau of Mines from a voluntary survey of U.S. operations. The one operation to which a survey request was sent responded, representing 100% of total production. However, to avoid disclosing company proprietary data, production and stock data were withheld from publication.

The strontium survey is also used to calculate the distribution of major strontium compounds by end use. Of the 12 operations to which a survey request was sent, 8 responded, representing an estimated 67% of the end-use data shown in table 3. Consumption for the nonrespondents was estimated using reported prior year consumption levels adjusted by trends in employment and industrial market patterns.

**Table 2.—Major producers of strontium compounds in 1985**

| Company | Location | Compounds |
|---|---|---|
| Chemical Products Corp | Cartersville, GA | Carbonate and nitrate |
| Mallinckrodt Inc | St. Louis, MO | Chloride. |
| Mineral Pigments Corp | Beltsville, MD | Chromate. |

## DOMESTIC PRODUCTION

With the closure of FMC Corp.'s Modesto, CA, plant in 1984, CPC became the sole domestic producer of strontium carbonate from imported celestite. Several other firms manufactured various strontium compounds from strontium carbonate in 1985.

Church & Dwight Co. Inc. purchased a 49% share in a Mexican producer of barium and strontium carbonates. Church & Dwight intended to market the strontium carbonate in the United States through its marketing and sales network.

## CONSUMPTION AND USES

Strontium carbonate used in the manufacture of faceplate glass for color television picture tubes accounted for more than one-half of domestic consumption of strontium compounds. Strontium carbonate was also used to make ferrite ceramic magnets and in the electrolytic production of zinc.

Strontium nitrate was used in pyrotechnics and signals. That sector remained the second largest consumer of strontium compounds. Other strontium compounds for domestic consumption included strontium chromate used as a corrosion inhibitor in pigments, strontium chloride used in the manufacture of toothpaste for sensitive teeth, and strontium phosphate used in fluorescent lights.

**Table 3.—U.S. estimated distribution of primary strontium compounds, by end use**

(Percent)

| End use | 1983 | 1984 | 1985 |
|---|---|---|---|
| Electrolytic production of zinc | 3 | 6 | 6 |
| Ferrite ceramic magnets | 9 | 11 | 12 |
| Pigments and fillers | 4 | 8 | 8 |
| Pyrotechnics and signals | 14 | 14 | 15 |
| Television picture tubes | 64 | 53 | 52 |
| Other | (1) | 1 | 1 |
| Unidentified | 6 | 7 | 6 |
| Total | 100 | 100 | 100 |

[1] Less than 1/2 unit.

## PRICES

The average value of imported celestite from Mexico, which was the sole supplier of the mineral in 1985, was $88.43 per short ton. Average values for imported strontium compounds variod according to the type of compound.

## FOREIGN TRADE

Mexico supplied all of the celestite imported by the United States. Canada, China, Japan, Mexico, and several countries in Western Europe were the sources of imports of various strontium compounds.

Because of the closure of FMC's facility in 1984, foreign competition for domestic strontium markets was strong. Imports of strontium materials in 1985 were more than those of the preceding year in all categories. Unwrought strontium metal imports increased more than six times the 1984 level. The leading suppliers of strontium carbonate, in descending order, were the Federal Republic of Germany, Mexico, and Canada. Strontium nitrate imports nearly doubled in response to the decrease in domestic supply.

According to the Port Import/Export Reporting Service of the Journal of Commerce, exports of various strontium compounds were about 38 tons. These compounds included the carbonate, chloride, chromate, peroxide, silicate, and zirconate of strontium.

**Table 4.—U.S. imports for consumption of strontium minerals[1] by country**

| Country | 1984 Quantity (short tons) | 1984 Value (thousands) | 1985 Quantity (short tons) | 1985 Value (thousands) |
|---|---|---|---|---|
| Madagascar | (2) | $1 | -- | -- |
| Mexico | 46,873 | 3,940 | 37,552 | $3,321 |
| Spain | 1,978 | 352 | -- | -- |
| Total | [3]48,852 | 4,293 | 37,552 | 3,321 |

[1] Celestite (strontium sulfate).
[2] Less than 1/2 unit.
[3] Data do not add to total shown because of independent rounding.

Source: Bureau of the Census.

### Table 5.—U.S. imports for consumption of strontium compounds and metal, by country

| Country | 1984 | | 1985 | |
|---|---|---|---|---|
| | Pounds | Value[1] | Pounds | Value[1] |
| Strontium carbonate, not precipitated: | | | | |
| Canada | 436 | $345 | -- | -- |
| Germany, Federal Republic of | 39,683 | 11,233 | -- | -- |
| Mexico | 84,000 | 23,880 | 186,384 | $51,256 |
| Spain | 39,683 | 9,423 | -- | -- |
| Total | 163,802 | 44,881 | 186,384 | 51,256 |
| Strontium carbonate, precipitated: | | | | |
| Canada | 158,733 | 66,935 | 119,049 | 35,169 |
| China | 829,547 | 253,331 | 37,478 | 11,003 |
| Germany, Federal Republic of | 5,586,138 | 1,577,834 | 9,676,889 | 2,955,649 |
| Mexico | 354,200 | 130,219 | 244,100 | 64,800 |
| Total | 6,928,618 | 2,028,319 | 10,077,516 | 3,066,621 |
| Strontium chromate:[2] | | | | |
| Belgium | 5,291 | 5,941 | 154,102 | 149,580 |
| France | 222,665 | 224,149 | 207,154 | 231,333 |
| Germany, Federal Republic of | 13,228 | 19,340 | 260,541 | 244,541 |
| Italy | -- | -- | 17,637 | 19,456 |
| Spain | 147,647 | 161,879 | 187,714 | 212,206 |
| United Kingdom | 4,698 | 13,574 | -- | -- |
| Total | 393,529 | 424,883 | 827,148 | 857,116 |
| Strontium nitrate: | | | | |
| Germany, Federal Republic of | -- | -- | 882 | 3,014 |
| Italy | 970,517 | 417,918 | 935,633 | 371,571 |
| Spain | 865,619 | 325,233 | 2,427,631 | 966,496 |
| Total | 1,836,136 | 743,151 | 3,364,146 | 1,341,081 |
| Strontium compounds, other: | | | | |
| Belgium | 441 | 390 | 7,716 | 9,450 |
| Germany, Federal Republic of | 22,391 | 22,913 | 58,863 | 55,379 |
| Japan | 157,364 | 109,954 | 261,795 | 175,069 |
| Netherlands | 7,726 | 11,598 | -- | -- |
| United Kingdom | -- | -- | 22,157 | 29,695 |
| Total | 187,922 | 144,855 | 350,531 | 269,593 |
| Strontium metal, unwrought: Canada | 1,424 | 17,980 | 9,052 | 86,160 |

[1] Customs value.

[2] Imported as strontium chromate pigment (TSUS 473.19).

Source: Bureau of the Census.

## WORLD REVIEW

**Canada.**—Timminco Ltd. won the bid for the mineral rights to a celestite-bearing deposit that had been mined from 1970 to 1976 by Kaiser Celestite Mining Ltd. Because the two beds of celestite have strontium sulfate grades from 45% to 55% and 60% to 70%, the ore would require beneficiation to achieve the commercially acceptable minimum of 90% strontium sulfate content.

**Mexico.**—Cía. Mineral la Valenciana S.A. completed construction of a 12,000-ton-per-year strontium carbonate plant at Torreón, Coahuila. The company, which was the largest celestite producer in the world, was the sole supplier to CPC in the United States.

Church & Dwight purchased a 49% interest in Sales y Oxidos, which produced barium and strontium carbonates at Monterrey. Plant capacity was expected to be increased to 8,800 tons per year of strontium carbonate by 1986.

**Table 6.—Strontium minerals: World production, by country[1]**

(Short tons)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Algeria[e] | 6,000 | 6,000 | 6,000 | 6,000 | 6,000 |
| Argentina | 342 | 855 | 742 | 440 | 550 |
| Iran[e] [3] | 5,500 | 5,000 | 5,100 | 5,100 | 5,100 |
| Italy | 7,382 | 3,607 | [e]3,600 | [r] [e]3,700 | 3,700 |
| Mexico | 45,574 | 84,917 | 41,343 | 35,264 | 35,300 |
| Pakistan | [r]317 | [r]513 | 149 | 622 | 750 |
| Spain | 39,683 | [r]38,470 | 38,000 | 29,760 | 30,000 |
| Turkey[e] | 16,500 | 16,500 | [4]42,808 | 38,600 | 38,600 |
| United Kingdom | 16,000 | 19,800 | 13,340 | 17,750 | 18,700 |
| Total | [r]137,298 | [r]125,662 | 151,082 | 137,236 | 138,700 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1] Table includes data available through June 10, 1986.

[2] In addition to the countries listed, China, Poland, and the U.S.S.R. produce strontium minerals, but output is not reported quantitatively, and available information is inadequate for formulation of reliable estimates of output levels.

[3] Year beginning Mar. 21 of that stated.

[4] Reported figure.

## WOLLASTONITE[7]

Wollastonite is a natural calcium silicate and has a theoretical composition of $CaO \cdot SiO_2$.

The tonnage of wollastonite sold or used by U.S. producers in 1985 was approximately the same as that of 1984. Specific data are withheld to avoid disclosing company proprietary data. The two producers, in descending order of output, were NYCO, a division of Processed Minerals Inc., Essex County, NY, and R. T. Vanderbilt Co. Inc., Lewis County, NY.

NYCO announced the opening of a pilot plant to perform a variety of reduced-scale functions for the development and application of specialty and surface modified minerals. The plant offers customers full replication of commercial processes in the use of NYCO products, providing information on the effect of process variables and enabling production conditions to be optimized in advance of commercial operation.[8]

Some of the major uses of wollastonite are as a filler in ceramic tile, marine wallboard, paint, plastics, and refractory liners in steel mills; and as a partial replacement for short-fibered asbestos in certain applications such as brake linings.

For use in paints, finer grades of wollastonite are employed, especially in the 325-mesh range. The mineral is fairly alkaline and is used in polyvinyl acetate paints to prevent undesirable acidity and to reduce corrosion of steel substrates. Wollastonite is also used in exterior architectural coating, especially in water-based paints, giving improved weatherability. It has also found use in traffic paints, and as an asbestos replacement in asphalt-based coatings.[9]

A comprehensive report published by Charles H. Kline & Co. Inc., Fairfield, NJ, deals with chemically modified minerals and forecasts a growth in consumption for these minerals from $110 million in 1984 to $150 million by the end of the century. This represents an average annual growth rate of approximately 6%. Several mineral fillers are discussed in the report, including wollastonite. These minerals are chemically treated with organic chemicals to improve bonding, processing, and moisture resistance within the matrix media. Chemical compounds such as stearates and silanes are used to produce the chemically modified minerals, which, in turn, are employed in plastics and rubbers. Chemically treated minerals were originally seen as a cost-effective way of reducing the volume of raw polymer material being used. However, during the past several years, developments have increased mineral compatability with the matrix polymer so that chemically treated fillers and extenders actually contribute to the products' eventual physical characteristics and performance.[10]

In Finland, Oy Partek AB planned to bring on-stream a new beneficiation plant that would increase capacity from 22,000 tons per year to 44,000 tons per year of wollastonite in 1986. The plant was to include an improved flotation process, increased automation, and wet high-intensity magnetic separation. Partek's mine at Lappeenranta had proven reserves of 4 million tons of ore. A newly discovered deposit 18 miles northwest of Lappeenranta had calculated reserves of approximately 22 million tons of ore. This deposit will undergo further investigation during the next few years. The increase in production capacity will enable the company to introduce new micronized grades of wollastonite, primarily for filler applications where high reinforcing performance is desired.[11]

Chemical Marketing Reporter, December 30, 1985, quoted prices for wollastonite, truckloads, f.o.b. plant, as $200 per ton for general grade, $140 per ton for 325 mesh, $160 per ton for 400 mesh, and $500 per ton for 1,250 mesh.

## ZEOLITES[12]

Domestic production of natural zeolites was approximately 13,000 short tons. Five companies mined clinoptilolite and chabazite in five States.

The Double Eagle Petroleum & Mining Co. leased its Castle Creek zeolite mine in Idaho to International Minerals & Chemical Corp. The deposit is composed of more than 90% clinoptilolite and has proven reserves in excess of 20 million tons.[13] Zeolite International Inc. developed and operated a zeolite deposit at Ash Meadows, CO. The deposit was leased from Anaconda Minerals Co., a subsidiary of Atlantic Richfield Co. The Ash Meadows deposit is a high-purity clinoptilolite deposit. The clinoptilolite was marketed for aquaculture, desiccation, solar energy, and gas separation.[14]

The Georgia Institute of Technology in Atlanta established a program to study the synthesis, characterization, catalytic, and absorption properties of molecular sieves and zeolites.[15] The program will be funded by industrial sponsors, who will receive royalty-free, nonexclusive licenses to the products of the center.

The use of zeolites as molecular sieves for absorbents and desiccant applications increased in 1985, replacing silica gel and activated alumina. Zeolites were estimated to account for 50% of the market, up from 33% in 1976.[16]

Zeolites are used in water treatment as ion exchangers.[17] Synthetic zeolites, in particular, are widely employed where water purity is critical to prevent scale buildup, such as in electric power station and other industrial boiler operations. Synthetic zeolite resins exchange sodium for calcium and magnesium to reduce the hardness of the water without affecting the total dissolved solids content. Natural zeolites are used less extensively. They do not possess the same cation exchange capacities of synthetic zeolites, but they are lower in cost, more resistant to attrition, and have greater affinities for some heavy cations. Several uses, both experimental and commercial, include ammonium-ion removal in wastewater treatment, odor control for fish farming, chicken farming, and in cat litter, and removal of heavy metal ions from nuclear, mine, and industrial wastewaters.

PQ Corp. began an expansion of its synthetic zeolite facility in Kansas City, KS, with construction of a new specialty zeolite catalyst plant in 1985.[18] The company planned to expand its zeolite product market from the current detergent-grade zeolite A. Sodium Y zeolite would be converted into an ultrastable zeolite Y and other Y derivatives for use as catalysts for petroleum refining and chemical synthesis. The plant would manufacture zeolites requiring either pressurized or atmospheric crystallization.

Union Carbide Corp. and its subsidiary, Katalistics International BV, ran commercial trials using newly developed zeolite catalysts based on ultrastable zeolites.[19] The new catalysts were reported to produce high-octane gasoline, rich in olefins, and to impede coke formation and aromatic condensation and offer a viable alternative to other methods of producing high octane levels, such as polymerization, isomerization, alkylation, or the addition of methanol.

The New Zealand Synthetic Fuels Co. began operation of the first commercial application of Mobil Oil Corp.'s methane-to-gasoline (MTG) process at their Motunui plant.[20] The key element of the MTG process is the ZSM-5 zeolite used in the process. With intersecting 6-angstrom-diameter channels, the zeolite allows hydrocarbons to boil in the gasoline range and limits products to short chain hydrocarbons. The MTG conversion is a new technology that may challenge traditional methods of producing synthetic fuels and organic feedstocks.

A private group called Inversiones BIMA, Buenos Aires, Argentina, applied for Government approval to build a $920 million MTG plant.[21] The planned plant capacity would be 1 million cubic meters of gasoline per year, with annual revenues from exports estimated at $300 million at 1985 world prices. This plant would be only the second commercial application of Mobil Oil's MTG process.

Several new zeolite deposits were discovered in the Angora, Yakut, and Buryat areas in Eastern Siberia.[22] The All-Union Institute of Geology, Geochemistry, and Minerals Raw Materials in Irkutsk set up a laboratory to study the mineralogical characteristics of zeolites from these deposits.

## TECHNOLOGY

The cesium exchange properties of several zeolitic tuffs and several synthetic zeolites were tested using equilibrium exchange reactions.[23] The zeolitic tuffs were composed of phillipsite, mordenite, clinoptilolite, erionite, chabazite, and analcime. Zeolitic tuffs composed of phillipsite had the best ion exchange characteristics over a range of solution concentrations. The phillipsite tuffs also reacted more favorably to heat treatment, used to immobilize the cesium in the structure, than other zeolites types. The significance of the exchange capacities and phase transformations of the phillipsite-rich tuffs is the potential to decontaminate nuclear waste solutions and fix cesium in the crystal structure to prevent removal by leaching with ground water.

Single metal atoms can be directed and attached to the intracrystalline cavities of some zeolites by using a solvated metal atom that can pass through the crystal structure and enter the α-cages while maintaining the integrity of the zeolite structure.[24] Bis(toluene)iron(o) and bis(toluene)cobalt(o) were filtered through faujasite zeolite Y at 173 to 193 K. Upon reaching room temperature, the bis(toulene)metal(o) complex decomposed to toluene and a metal atom, leaving metal atoms in the crystal structure. Metal atom clusters then formed when single atoms diffused through the structure and agglomerated. The cluster sizes are controlled by the initial atom loading in the structure and the size of the α-cage. This technique was proven to be a nondestructive means of depositing zerovalent metal atoms in the zeolite structure. Zeolites containing site-specific metal clusters may be potentially useful as catalysts for oil, gas, and petroleum production.

Aluminosilicate zeolites were synthesized using a nonaqueous solvent technique.[25] Usually, zeolites are synthesized from alkaline aqueous solutions or by solid-state reactions between silica and alumina salts at high temperatures. Using a nonaqueous technique, pure silica zeolites, called silica-sodalite, were synthesized. This research suggested that other framework aluminosilicates could be synthesized in silica-rich or pure silica forms.

Union Carbide developed a molecular sieve with many properties similar to zeolites.[26] The sieves, called silicoaluminophosphates (SAPO), formed in a similar manner as zeolites, crystallizing at temperatures from 100° to 200° C from reactive mixtures containing template materials. The template materials, usually organic amines or quaternary ammonium compounds, were retained within the products. SAPO were expected to be useful as absorbents, ion exchange agents, catalysts, and catalyst supports.

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[2] Prepared by James P. Searls, physical scientist.

[3] Prepared by Sarkis G. Ampian, physical scientist.

[4] Prepared by A. C. Meisinger, industry economist.

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# Other Metals

## By Staff, Divisions of Nonferrous and Ferrous Metals

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## ARSENIC[1]

In 1985, ASARCO Incorporated terminated copper smelting operations and associated byproduct arsenic trioxide recovery at Tacoma, WA, although shipments of arsenic trioxide from stocks and limited production from cleanup operations continued. Imports of arsenic trioxide increased markedly as a result of increased demand for arsenical wood preservatives and the decline in domestic shipments of trioxide. Expanded world capacity more than met the increased demand for arsenic and its compounds, and prices remained unchanged throughout the year.

**Domestic Data Coverage.**—Arsenic trioxide was produced by one U.S. company, which voluntarily reported its production to the Bureau of Mines.

**Legislation and Government Programs.**—On July 13, 1984, the Environmental Protection Agency (EPA) issued a "Notice of Intent To Cancel Registrations of Pesticide Products Containing Creosote, Pentachlorophenol, and the Inorganic Arsenicals" and announced that certain modifications to the terms and conditions of registration for wood preservative uses of the three chemicals were required to avoid cancellation. In addition, it established workplace regulations and air monitoring criteria at wood preserving plants and required wood pressure treaters to provide consumer information sheets on the safe handling and disposal of treated wood. As a result of challenges filed by the wood preservative industry, EPA, in several separate actions during 1984 and 1985, stayed the effective date of the modifications to the terms and conditions of registration.[2]

On September 30, Public Law 96-510, the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund), expired. Under Superfund, arsenic was taxed at a rate of $4.45 per ton, and arsenic trioxide was taxed at a rate of $3.41 per ton. At yearend, several bills to reauthorize Superfund taxing authority were under consideration by Congress.

### DOMESTIC PRODUCTION

During 1985, production of arsenic trioxide and metal by Asarco, the only domestic producer, declined from that of 1984 by 68%. Asarco produced arsenic trioxide at its Tacoma, WA, copper smelter as a byproduct of the smelting of imported high-arsenic copper concentrates and ores, mainly from Chile and the Philippines, as well as from domestic arsenic-bearing residues and concentrates. Arsenic metal was produced from high-purity imported arsenic trioxide; the low grade and antimony contamination of the arsenic trioxide produced at Tacoma made it unsuitable for metal production.

In March, copper smelting operations at Tacoma, WA, were permanently terminated. The company cited low copper prices, a shortage of suitable concentrates, and the estimated $150 million cost of meeting Federal, State, and local sulfur dioxide emissions standards as the reasons for closure. Although copper smelting ceased in March, production of arsenic trioxide from stocks of residues continued throughout the year. By yearend, production of arsenic trioxide and metal had ended, though shipments of arsenic metal and trioxide from stocks were expected to continue through the first half of 1986. Asarco was reportedly investigating alternatives to its Tacoma roasting process for processing arsenic-bearing residues generated at other Asarco nonferrous smelters.

In addition to purchasing refined arsenic trioxide, Koppers Co. Inc., a major producer of arsenical wood preservatives, produced refined arsenic trioxide at its plant in Conley, GA, from low-grade material imported from Canada. Arsenic acid was produced from the trioxide and was marketed or consumed internally in the production of chromated copper arsenate (CCA) wood preservatives. A second company, Mineral Research Development Corp., Charlotte, NC, produced arsenic acid for use in wood preservatives directly from low-grade Canadian material. Mineral Research was purchased by Laporte Industries Ltd. of the United Kingdom, which also purchased Chemical Specialties Inc., a producer of CCA wood preservatives, in Valdosta, GA. Chemical Specialties expanded its CCA mixing capacity, making it one of the largest domestic producers of arsenical wood preservatives. W. R. Metals Inc., formerly Williams Strategic Metals Inc., Wheat Ridge, CO, produced arsenic acid for sale to the wood preservative industry from arsenic-bearing lead smelter flue dusts containing about 50% arsenic at its plant in Wyoming.

High-purity arsenic metal for use in electronic devices was refined from commercial-grade metal by at least two companies—Asarco at its Globe, CO, plant, and Canyonlands 21st Century Corp. at its Blanding, UT, facility. By yearend, Canyonlands had declared bankruptcy and was closed; its assets were to be sold at auction.

## CONSUMPTION AND USES

Arsenic compounds, principally arsenic trioxide, accounted for 98% of the arsenic consumed in 1985. Demand for arsenic and its compounds was estimated to be equivalent to about 18,000 metric tons of contained arsenic, up slightly from that of 1984. Domestic production accounted for about 21% of demand. Three major producers of arsenical wood preservatives and four producers of agricultural chemicals accounted for most of the domestic consumption of arsenic trioxide. Arsenic acid, produced from arsenic trioxide, was used directly, or as an intermediate product. The estimated end-use distribution of arsenic was 67% in wood preservatives, 25% in agricultural products (principally herbicides and desiccants), 4% in glass, 2% in metallic form in nonferrous alloys and electronics, and 2% in other uses (animal feed additives, pharmaceuticals, etc.).

CCA, by far the most important of the arsenical wood preservatives, is a waterborne, leach-resistant wood preservative prepared by mixing arsenic acid with copper oxide or sulfate and chromic acid. It is used to pressure treat a variety of wood products that are subject to outdoor or inground exposure, and may serve to extend the service life of wood by a factor of at least 15.[3] According to data published by the American Wood Preservers Institute for 1983 and 1984, there were 547 wood treating plants operating in the United States in 1984, 342 of which treated with waterborne (96% CCA) preservatives. The plants treated 499.1 million cubic feet of wood products in 1984: 301.7 million with waterborne preservatives, 137.6 million with creosote solutions, 53.6 million with pentachlorophenol, and 6.2 million with fire retardant chemicals. Although total production of treated wood in 1984 was 12% above 1983 production levels, production of wood products treated with waterborne preservatives increased by 17%. Of the wood products treated with waterborne preservatives, 76% was lumber; 7%, timbers; 5%, fence posts; 4%, poles; and 8%, other products.[4]

The principal agricultural market for arsenicals was in cotton growing, where arsenic acid was used as a desiccant to aid in mechanical stripper harvesting of cotton, and other arsenical chemicals, such as monosodium methanearsonate (MSMA) and disodium methanearsonate (DSMA), were used as herbicides for control of grassy and broadleaf weeds. Cotton planting in 1985 declined slightly from 1984 levels. To a lesser extent, arsenical herbicides were used in noncrop areas such as railroad right-of-ways.

Arsenic trioxide and arsenic acid were

used in the glass industry primarily as a fining agent to remove tiny, dispersed air bubbles and also as a decolorizing agent. Use in recent years has been limited to the pressed and blown glass sector for products such as tableware, lead glass, optical glass, and glass ceramics.

The bulk of metallic arsenic was used in lead- and copper-based alloys as a minor additive (about 0.01% to 0.5%) to increase strength in the posts and grids of lead-acid storage batteries and to improve corrosion resistance and tensile strength in copper alloys. A relatively small amount, less than 10 tons, of high-purity arsenic metal was used in the electronics industry. Gallium arsenide and its alloys have been used in such products as light-emitting diodes and displays, room-temperature lasers, microwave devices, solar cells, and photoemissive surfaces. Development of gallium arsenide integrated circuits (IC) continued to gain momentum during 1985, the first commercially available gallium arsenide IC's having become available early in 1984. Because gallium arsenide devices, compared with silicon devices, have higher operating frequencies, lower power consumption, lower noise, and superior resistance to radiation, they were expected to have extensive military applications.

## PRICES

The price of domestically produced crude arsenic trioxide, guaranteed minimum 95% purity, remained constant throughout the year at $0.33 per pound for carload quantities, as supplies of trioxide remained plentiful despite the closure of Asarco's Tacoma, WA, smelter. Prices for imported refined trioxide also remained constant throughout the year, Mexican trioxide having a published price of $0.42 per pound.

The price of domestically produced arsenic metal, marketed in 250-pound drums or 2,000-pound pallets, remained constant at $2.10 per pound. High-purity arsenic metal for electronics usage was sold in evacuated or argon-filled ampules to inhibit oxidation. While domestic material, guaranteed to be 99.999% pure, sold for $100 per kilogram, imported material of higher guaranteed purity cost as much as $100 per gram in small quantities.

### Table 1.—Arsenic price quotations

(Cents per pound, yearend)

| | 1983 | 1984 | 1985 |
|---|---|---|---|
| Trioxide, domestic, 95% $As_2O_3$, f.o.b. Tacoma, WA[1] | 33 | 33 | 33 |
| Trioxide, Mexican, 99.13% $As_2O_3$, f.o.b. Laredo, TX[2] | 45 | 42 | 42 |
| Metal, domestic, 99% As[1] | 225 | 210 | 210 |

[1] Producers' quote.
[2] Metals Week.

## FOREIGN TRADE

In response to increased demand and curtailed domestic shipments, imports of arsenic trioxide increased by 18% in 1985. Imports of arsenic trioxide from Canada were largely arsenic trioxide-bearing flue dusts, generated during the roasting of arsenical gold ores by Campbell Red Lake Mines Ltd. and Giant Yellowknife Mines Ltd. A small portion of Canadian imports of arsenic trioxide were from Cominco Ltd.'s new arsenic recovery plant associated with the Con Mine in the Northwest Territories.

Small quantities of low-grade, minimum 97%, arsenic trioxide were received from new arsenic refineries in Chile and the Philippines. Industry sources indicated that major wood preservers were testing this material as a substitute for domestic crude material.

## Table 2.—U.S. imports for consumption of arsenicals, by class and country

| Class and country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| **Arsenic trioxide:** | | | | | | |
| Australia | 37 | r$10 | -- | -- | 30 | $3 |
| Belgium-Luxembourg | 946 | 848 | 843 | $654 | 1,498 | 1,074 |
| Bolivia | -- | -- | 16 | 4 | 98 | 67 |
| Canada | 2,525 | 542 | 4,767 | 1,468 | 3,669 | 4,059 |
| Chile | -- | -- | -- | -- | 191 | 101 |
| China | 17 | 36 | -- | -- | 105 | 46 |
| France | 667 | 706 | 1,261 | 849 | 3,608 | 2,264 |
| Germany, Federal Republic of | 1 | 6 | ([1]) | 1 | -- | -- |
| Japan | ([1]) | 1 | -- | -- | 371 | 184 |
| Korea, Republic of | -- | -- | 68 | 51 | -- | -- |
| Mexico | 2,531 | 2,700 | 3,115 | 2,820 | 3,399 | 2,946 |
| Namibia | 16 | 11 | -- | -- | -- | -- |
| Netherlands | -- | -- | -- | -- | 236 | 149 |
| Philippines | -- | -- | -- | -- | 23 | 10 |
| Portugal | -- | -- | -- | -- | 18 | 12 |
| South Africa, Republic of | 17 | 18 | -- | -- | 113 | 72 |
| Sweden | 3,430 | 3,528 | 3,914 | 3,608 | 2,996 | 3,014 |
| United Kingdom | -- | -- | -- | -- | 116 | 58 |
| Total[2] | 10,186 | 8,406 | 13,985 | 9,454 | 16,472 | 14,059 |
| **Arsenic acid:** | | | | | | |
| Australia | 74 | 54 | 21 | 15 | -- | -- |
| Canada | -- | -- | ([1]) | 1 | -- | -- |
| France | 34 | 34 | -- | -- | -- | -- |
| Germany, Federal Republic of | ([1]) | 2 | ([1]) | ([1]) | -- | -- |
| Japan | -- | -- | ([1]) | 1 | -- | -- |
| Mexico | -- | -- | 65 | 57 | -- | -- |
| United Kingdom | 2,277 | 2,304 | 2,420 | 1,973 | 1,993 | 1,360 |
| Total | 2,385 | 2,394 | 2,506 | 2,047 | 1,993 | 1,360 |
| **Arsenic sulfide:** | | | | | | |
| Canada | ([1]) | ([1]) | 20 | 3 | -- | -- |
| Japan | 1,127 | 1,522 | ([1]) | 1 | -- | -- |
| Philippines | -- | -- | -- | -- | 2 | 2 |
| Total | 1,127 | 1,522 | 20 | 4 | 2 | 2 |
| **Arsenic metal:** | | | | | | |
| Belgium-Luxembourg | ([1]) | 7 | -- | -- | -- | -- |
| Canada | 6 | 328 | 21 | 712 | 23 | 644 |
| China | 128 | 428 | 102 | 350 | 136 | 311 |
| France | -- | -- | ([1]) | 4 | -- | -- |
| Germany, Federal Republic of | 1 | 111 | 2 | 215 | 2 | 195 |
| Hong Kong | -- | -- | -- | -- | 47 | 158 |
| Japan | ([1]) | 30 | 1 | 127 | 22 | 171 |
| Netherlands | -- | -- | 5 | 19 | -- | -- |
| Sweden | 108 | 435 | 158 | 614 | 171 | 642 |
| Taiwan | -- | -- | -- | -- | 5 | 17 |
| United Kingdom | ([1]) | 62 | 15 | 87 | ([1]) | 12 |
| Total[2] | 243 | 1,401 | 304 | 2,127 | 407 | 2,150 |
| **Lead arsenate:** | | | | | | |
| Canada | -- | -- | 3 | 3 | 29 | 13 |
| Germany, Federal Republic of | ([1]) | 2 | 3 | 9 | -- | -- |
| Japan | -- | -- | -- | -- | ([1]) | 1 |
| Netherlands | -- | -- | 12 | 26 | 66 | 128 |
| Peru | 17 | 35 | 54 | 105 | 68 | 144 |
| United Kingdom | -- | -- | 1 | 2 | -- | -- |
| Total[2] | 17 | 37 | 73 | 145 | 162 | 287 |
| **Sodium arsenate:** | | | | | | |
| France | -- | -- | -- | -- | 20 | 7 |
| Other | ([1]) | 2 | 1 | 3 | ([1]) | 3 |
| Total | ([1]) | 2 | 1 | 3 | 20 | 10 |

See footnotes at end of table.

**Table 2.—U.S. imports for consumption of arsenicals, by class and country —Continued**

| Class and country | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Arsenic compounds, n.e.c.: |  |  |  |  |  |  |
| Canada | -- | -- | 17 | $588 | -- | -- |
| Mexico | -- | -- | -- | -- | 23 | $52 |
| Sweden | 17 | $22 | 17 | 20 | -- | -- |
| United Kingdom | 9 | 108 | 1 | 165 | ([1]) | 66 |
| Other | ([1]) | 28 | ([1]) | 29 | ([1]) | 13 |
| Total[2] | 26 | 158 | 35 | 801 | 23 | 131 |

[r] Revised.

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

**Table 3.—U.S. import duties for arsenicals**

| Item | TSUS No. | Most favored nation (MFN) |  | Non-MFN |
|---|---|---|---|---|
|  |  | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Arsenic metal | 632.04 | 0.8 cent per pound | Free | 6.0 cents per pound. |
| Trioxide and sulfide | 417.62, 417.60 | Free | do | Free. |
| Other compounds | 417.64 | 4.0% ad valorem | 3.7% ad valorem | 25% ad valorem. |

## WORLD REVIEW

Arsenic trioxide was produced in at least 16 countries as a byproduct of processing nonferrous ores. The nine principal producing countries accounted for about 90% of world production. With the exception of Canada, which had at least two producers of crude trioxide and one producer of refined trioxide, the production in each of the nine countries was principally from one company.

The closing of Asarco's Tacoma, WA, smelter, which had been the largest market economy country producer of arsenic trioxide, did not result in a shortage of world supplies. New production facilities in Chile and the Philippines have resulted in a world oversupply of arsenic, with much of their 1985 production being stockpiled. Significant stocks of arsenic trioxide were also reported being held by Western European producers. In addition, during 1985, Société des Mines et Produits Chimiques de Salsigne S.A., in France, which produced arsenic from gold-silver-copper ores, installed a new roaster to treat high-arsenic concentrates and expanded its arsenic trioxide production capacity by about 50%.

In addition to the United States, which accounted for more than 60% of the world demand, the United Kingdom was a major consumer of arsenic trioxide and metal. There were at least three British companies, Rentokil PLC, Hickson Timber Products Ltd., and Laporte Industries, producing arsenical wood preservatives domestically and abroad. At least two British companies, Johnson Matthey Chemicals Ltd. and MCP Electronic Materials Ltd., produced high-purity arsenic metal.[5]

### Table 4.—Arsenic trioxide:[1] World production, by country[2]

(Metric tons)

| Country[3] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Belgium[e] | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 |
| Bolivia | 127 | 261 | 107 | 144 | 400 |
| Canada[e] [4] | [r]2,000 | [r]2,000 | [r]2,000 | [r]3,000 | 3,000 |
| Chile[5] | -- | -- | -- | [e]3,500 | 4,000 |
| France | [e]5,200 | [r] [e]6,000 | 4,727 | 3,828 | 4,000 |
| Germany, Federal Republic of[e] | 360 | 360 | 360 | 360 | 360 |
| Japan[e] | [e]95 | 100 | 300 | 500 | 500 |
| Korea, Republic of | 170 | 306 | 560 | NA | NA |
| Mexico | 6,517 | 4,740 | 4,557 | 5,496 | 5,000 |
| Namibia[7] | 1,370 | 1,895 | 1,126 | 2,504 | 2,500 |
| Peru[8] | 2,164 | 1,663 | 1,110 | 887 | 800 |
| Philippines[9] | -- | -- | -- | -- | 5,000 |
| Portugal[e] | [e]257 | 200 | [r]180 | 180 | 170 |
| Sweden[e] [10] | 6,900 | 7,200 | 5,300 | 5,900 | 6,000 |
| U.S.S.R.[e] | 7,750 | 7,800 | 7,900 | 8,000 | 8,100 |
| United States | 7,800 | 8,000 | 7,300 | 6,800 | [e]2,200 |
| Zimbabwe | 21 | -- | -- | -- | -- |
| Total | [r]43,731 | [r]43,525 | 38,527 | 44,099 | 45,030 |

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1] Including calculated arsenic trioxide equivalent of output of elemental arsenic and arsenic compounds other than arsenic trioxide where inclusion of such materials would not duplicate reported arsenic trioxide production.

[2] Table includes data available through June 10, 1986.

[3] Austria, China, Czechoslovakia, the German Democratic Republic, Hungary, Spain, the United Kingdom, and Yugoslavia have produced arsenic and/or arsenic compounds in previous years, but information is inadequate to make reliable estimates of output levels, if any.

[4] Figures include estimated production of low-grade dusts that were exported to the United States for further refining.

[5] Chile began producing arsenic trioxide during 1983 from the El Indio gold-copper ores; however, it was not of marketable quality and required further refining by foreign producers. It has not been listed separately to avoid double counting.

[6] Reported figure.

[7] Output of Tsumeb Corp. Ltd. only.

[8] Output of Empresa Minera del Centro del Perú (Centromín Perú).

[9] The Philippines may have had some arsenic output in 1984 from the Philippine Associated Smelting and Refining Corp. (PASAR) copper smelter, but available data are not adequate to make reliable estimates of output levels, if any.

[10] Based on arsenic trioxide exported plus the arsenic trioxide equivalent of the output of metallic arsenic exported.

## TECHNOLOGY

CSS Management Inc., in Skykomish, WA, in cooperation with the Bureau of Mines, developed a process to leach its gold-bearing arsenical copper flotation concentrate. Its concentrates had previously been processed at Asarco's Tacoma, WA, smelter. The process is based on a patented calcium-chloride, compressed-air leaching technology developed at the Bureau's Reno Research Center to process arsenic-bearing complex sulfides.[6] The copper and precious metals are extracted by leach solution at elevated temperatures and then selectively precipitated. The arsenic remains with the residue in an insoluble form. CSS was exploring the application of the process to high-arsenic flue dusts accumulated at the closed Anaconda copper smelter in Montana.[7]

Researchers at the Montana College of Mineral Science and Technology, Butte, MT, investigated methods of stabilization for permanent disposal of arsenic and other heavy metals contained in the flue dusts generated during copper smelting. Analysis of flue dusts stockpiled at various smelters revealed arsenic contents of up to 29.4%. The researchers found that by low-temperature roasting of the flue dusts with lime, the arsenic was converted to calcium arsenate and calcium arsenite, which could be effectively dissolved in copper reverberatory slags. Leach tests on the solidified slags indicated low arsenic extractive rates, making them suitable for outdoor storage.[8] Other research at the Montana College of Mineral Science, with support from the Bureau of Mines Mineral Industry Waste Treatment and Recovery Generic Center at Butte, involved the removal of arsenic from lead smelter speiss. More than 98% of the arsenic was removed by volatilizing it in the presence of sulfur under a carbon dioxide atmosphere at 800° C. Arsenic removed from the speiss was deposited on the reactor wall as elemental arsenic.[9]

Rapid advances continued to be made in the commercial development of gallium arsenide IC technology, and major investments in new facilities continued. Ford Motor Co., in a major diversification move, began production of gallium arsenide IC's at a new $33 million facility in Colorado Springs, CO. Ford reportedly planned to produce gallium arsenide chips for use in electronic data processing, instrumentation and testing, telecommunications, and aerospace applications. The plant, when fully operational, was expected to produce about 25,000 wafers per year.[10]

Improvement in the techniques for epitaxial growth of gallium arsenide crystal layers on either silicon or gallium arsenide substrates was a major research focus. Bell Communications Research, Livingston, NJ, unveiled a new crystal growth process that involved the concept of floating wafers while growing crystal layers on them. Using its "vapor levitation epitaxy" (VLE) method, the company reportedly produced ultrathin layers of gallium arsenide and other semiconductor materials in the exceptionally pure state essential to fiber-optic communications systems.[11] Another process, developed at the University of Illinois, involved the use of molecular-beam epitaxy to deposit nearly perfect layers of gallium arsenide onto silicon wafer substrates. Use of silicon wafer substrates avoids some of the brittleness, size limitations, and poor thermal conductivity of gallium arsenide substrates.[12]

## CESIUM AND RUBIDIUM[13]

Cesium, usually in the form of chemical compounds, was used mainly in research and development, including the development of magnetohydrodynamic (MHD) electric power generators, thermionic energy converters, and biological research. Commercially, cesium was used in electronic, photoelectric, and medical applications. Rubidium, usually in the form of chemical compounds, also was used mainly in research and development. It was also used commercially in electronic and medical applications.

**Domestic Data Coverage.**—Domestic data for cesium and rubidium are developed by the Bureau of Mines from a voluntary survey of U.S. operations. Of the four operations to which a survey request was sent, all responded, but only one company reported production of cesium and rubidium products. Production data are withheld to avoid disclosing company proprietary data.

### DOMESTIC PRODUCTION

Small quantities of cesium metal and compounds were produced from pollucite ore imported from Canada and Zimbabwe. Rubidium metal and compounds were produced from imported lepidolite ores.

The only producer of cesium and rubidium metals and compounds was the KBI Div. of Cabot Corp. at its plant at Revere, PA. The Callery Chemical Co., Callery, PA, a producer in past years, retained its production capacity and was considered a potential supplier.

### CONSUMPTION AND USES

Data concerning specific end uses and consumption patterns for cesium and rubidium and their compounds were not available. Cesium and rubidium and their respective compounds were interchangeable in most applications, although cesium compounds were most widely accepted because of their availability and price advantages.

More than 75% of the cesium and rubidium consumed in the United States was used in research. The principal use in this application was developmental research on direct energy-conversion devices, such as MHD generators, solar photovoltaic cells, and thermionic and high-temperature Rankine-cycle turboelectric power generators. Commercial consumption included uses for high-voltage rectifying tubes and for infrared lighting. Cesium chloride was used in photoelectric cells because its color sensitivity is higher than that of other alkali salts.

### PRICES

Prices of rubidium compounds increased 10% in 1985, while prices of cesium compounds remained unchanged. Metal prices did not change from the 1984 levels. At yearend, cesium metal was $275 per pound for technical-grade and $375 per pound for high-purity metal. Rubidium metal prices were $300 per pound for technical-grade and $375 for high-purity metal. All price data were obtained from the KBI Div. of Cabot.

### Table 5.—Prices of selected cesium and rubidium compounds

(Base price per pound[1])

| Compound | 1983 |  | 1984[2] |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Technical grade | High-purity grade | Technical grade | High-purity grade | Technical grade | High-purity grade |
| Cesium bromide | $34.25 | $69.50 | $36.80 | $74.70 | $36.80 | $74.70 |
| Cesium carbonate | 34.25 | 69.50 | 36.80 | 74.70 | 36.80 | 74.70 |
| Cesium chloride | 36.50 | 72.50 | 39.20 | 78.00 | 39.20 | 78.00 |
| Cesium fluoride | 43.50 | 80.00 | 46.80 | 86.00 | 46.80 | 86.00 |
| Cesium hydroxide | 41.25 | 78.00 | 44.40 | 83.90 | 44.40 | 83.90 |
| Rubidium carbonate | 83.50 | 125.00 | 89.80 | 134.40 | 98.80 | 147.80 |
| Rubidium chloride | 84.50 | 126.00 | 90.90 | 135.50 | 100.00 | 149.10 |
| Rubidium fluoride | 91.00 | 132.00 | 97.80 | 141.90 | 107.60 | 156.10 |
| Rubidium hydroxide | 91.00 | 132.00 | 97.80 | 141.90 | 107.60 | 156.10 |

[1] For quantities of less than 100 pounds, f.o.b. Revere, PA, excluding packaging costs.
[2] Effective Oct. 1, 1984.

Source: Cabot Corp. (KBI Div.).

## FOREIGN TRADE

The quantity of cesium compounds imported in 1985 was approximately equal to that of 1984. Most cesium compounds were imported from the Federal Republic of Germany. Trade data on raw materials and metal were not available.

### Table 6.—U.S. imports for consumption of cesium compounds, by class and country

| Class and country | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity (pounds) | Value | Quantity (pounds) | Value | Quantity (pounds) | Value |
| Cesium chloride: |  |  |  |  |  |  |
| Germany, Federal Republic of | 13,655 | $507,876 | 25,050 | $741,468 | 20,452 | $630,635 |
| Netherlands | 220 | 10,949 | 110 | 6,465 | 33 | 1,887 |
| Norway | -- | -- | -- | -- | 362 | 11,335 |
| Sweden | -- | -- | 18 | 884 | 115 | 7,367 |
| United Kingdom | -- | -- | -- | -- | 192 | 5,464 |
| Total | 13,875 | 518,825 | 25,178 | 748,817 | 21,154 | 656,688 |
| Cesium compounds, n.s.p.f.: |  |  |  |  |  |  |
| Austria | 13 | 685 | -- | -- | -- | -- |
| Canada | 2,406 | 2,093 | 520 | 4,100 | -- | -- |
| German Democratic Republic | -- | -- | -- | -- | 119 | 2,625 |
| Germany, Federal Republic of | 2,930 | 94,532 | 18,206 | 626,885 | 28,358 | 735,785 |
| Greece | -- | -- | -- | -- | 110 | 2,726 |
| Israel | -- | -- | 100 | 30,000 | -- | -- |
| Japan | -- | -- | 210 | 60,087 | 170 | 32,250 |
| Netherlands | -- | -- | 231 | 11,980 | -- | -- |
| United Kingdom | 3 | 397 | 9,207 | 69,925 | 626 | 164,468 |
| Total | 5,352 | 97,707 | 28,474 | 802,977 | 29,383 | 937,854 |

Source: Bureau of the Census.

### Table 7.—U.S. import duties for cesium and rubidium

| Item | TSUS No. | Most favored nation (MFN) |  | Non-MFN |
|---|---|---|---|---|
|  |  | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Ore and concentrate | 601.66 | Free | Free | Free. |
| Cesium | 415.10 | 6.1% ad valorem | 5.3% ad valorem | 25% ad valorem. |
| Cesium chloride | 418.50 | 4.5% ad valorem | 4.0% ad valorem | Do. |
| Other cesium compounds | 418.52 | 4.3% ad valorem | do | Do. |
| Rubidium | 415.40 | 4.0% ad valorem | 3.7% ad valorem | Do. |
| Rubidium compounds | 423.00 | do | do | Do. |

### WORLD REVIEW

The Tantalum Mining Corp. of Canada Ltd.'s mine at Bernic Lake, Canada, the major world source of the cesium ore pollucite and the rubidium ore lepidolite, remained on standby throughout 1985. The mine suspended operations at the end of 1982 owing to weak markets and large inventories.

### TECHNOLOGY

A new commercial use for radioactive cesium for the sterilization of medical instruments was reported. Large shipments of the material were reportedly made for the Hanford, WA, nuclear reservation to two firms in Colorado and Ohio.[14]

Cornell University reportedly purchased 20 tons of thallium-activated cesium iodide single crystals, used for detecting high-energy gamma rays, from Horiba Ltd., Kyoto, Japan. The cesium material reportedly is easier to fabricate and has a higher resistance to humidity than the sodium iodide used in conventional detectors.[15]

## GERMANIUM[16]

The estimated domestic production and consumption of refined germanium increased compared with those in 1984. Infrared systems and fiber optics continued to be the major markets for germanium.

**Domestic Data Coverage.**—Domestic refinery production and consumption data for germanium are estimated by the Bureau of Mines based on discussions with domestic producers.

**Legislation and Government Programs.**—On September 20, the EPA issued final regulations under the Clean Water Act for nonferrous metals manufacturing operations that limit the discharge of pollutants into navigable waters and into publicly owned treatment works. The primary and secondary germanium and gallium subcategory, 1 of 25 subcategories covered by this regulation, set limits on effluent discharges from both new and existing plants. Daily and monthly average maximums on the arsenic, fluoride, lead, and zinc content of effluents emanating from these plants were specified. Since the germanium content of these effluents, previously proposed for regulation, was expected to be controlled by best practical technology methods, the EPA decided that any specific limitations on this metal would be made on a case-by-case basis.[17]

On May 23, the U.S. Department of Commerce, with the approval of the Federal Emergency Management Agency, published National Defense Stockpile Purchase Specifications for refined intrinsic germanium metal. As of December 31, 1985, the stockpile goal remained at 30,000 kilograms; however, no germanium metal had been acquired.

On July 8, the President approved the National Security Council (NSC) recommendations for modernizing the strategic and critical materials stockpile. Under the NSC proposal, the National Defense Stockpile would be structured into two tiers. Tier I would contain materials required by military, industrial, and essential civilian users during a military conflict that would not be available from domestic or reliable foreign sources. Tier II would contain a supplemental reserve of materials already possessed by the Government. Germanium was included in tier I of this proposal with a goal of 146,049.4 kilograms. At yearend, this proposal was under consideration by the Congress. The Department of Defense Authorization Act, 1986 (Public Law 99-145), signed by the President on November 8, 1985, stated that no action may be taken before October 1, 1986, to implement or administer any change in a stockpile goal in effect on October 1, 1984, that results in a reduction in the quality or quantity of any strategic and critical material to be acquired for the National Defense Stockpile.

### DOMESTIC PRODUCTION

Domestic refinery production from both primary and secondary materials was estimated to be 22,000 kilograms. Based on the published U.S. producer price for refined germanium metal, the approximate value of production was $23 million.

Refined germanium products were produced by Eagle-Picher Industries Inc., Quapaw, OK; KBI Div. of Cabot, Revere, PA; and Atomergic Chemetals Corp., Plainview, NY.

In September, Rare Materials International Inc. reported the permanent closure and dismantling of its 1,200-kilogram-per-year germanium production facility in Irving, TX.

The Jersey Minière Zinc Co. in Clarksville, TN, continued to produce germanium-rich residues as a byproduct of processing zinc ores from its Gordonsville and Elmwood Mines. These residues reportedly were shipped to Métallurgie Hoboken-Overpelt SA (MHO) in Belgium for germanium recovery and refining.

Startup problems continued to delay the opening of Musto Explorations Ltd.'s primary gallium and germanium recovery plant near St. George, UT. The plant reportedly began limited production of 99.9%-pure gallium in October, but full-scale gallium production was postponed until 1986. The germanium production circuit was reportedly nearing completion by yearend 1985. Development continued on the Apex Mine ore zone, which reportedly contained recoverable quantities of copper, silver, and zinc, as well as germanium and gallium. The plant was the only operation in the world to recover germanium or gallium as principal products, and, when fully operational, the plant's annual production capacity was expected to be 17,900 kilograms of germanium and 10,000 kilograms of gallium.

According to a report published by the U.S. Geological Survey, the Apex Mine ore body was defined as a goethite-limonite-hematite zone that contained local concentrations of jarosite, azurite, malachite, and other supergene copper, iron, lead, and zinc minerals. Most of the copper-rich ore at the Apex Mine was removed during previous mining operations, leaving behind the iron oxide minerals in which most of the germanium was concentrated.[18]

## CONSUMPTION AND USES

The consumption of germanium was estimated at 38,000 kilograms, a slight increase compared with that of 1984. The estimated consumption pattern by end use of germanium in 1985 was as follows: infrared systems, 65%; fiber optics, 15%; gamma-ray, X-ray, and infrared detectors, 5%; semiconductors, 5%; and other, 10%.

The largest end use for germanium continued to be in infrared optics, especially military use in guidance and weapon-sighting systems. Germanium-containing lenses and windows transmit thermal radiation in a manner similar to visible light transmission by optical glass. Other important uses for germanium glass included nonmilitary surveillance and monitoring systems in fields such as satellite systems and fire alarms.

Another important market for germanium was in fiber-optic cables used in telecommunications systems. Fiber-optic systems were used as replacements for conventional wire telecommunication systems and were finding increased use in existing underground conduits where space was often limited. Fiber-optic systems provided a compact, short-circuit-free transmission medium that was not susceptible to distortion by an electromagnetic field and could not be tapped by currently available technology. Although not used in all fiber-optic systems, germanium was an important constituent in many fiber-optic cables.

Pirelli Cable Corp. of Union, NJ, announced the construction of a new fiber-optic cable manufacturing facility near Lexington, SC. The plant was expected to begin operations in early 1986. This installation would be the third Pirelli plant producing fiber-optic cables in North America; the other two were in Wallingsford, CT, and in Surrey, British Columbia, Canada.[19] In April, International Telephone & Telegraph Corp.'s Electro-Optical Products Div. announced the opening of a high-volume, fiber-optic cable production plant in Worchester, MA.[20]

Santa Fe Southern Corp. and Norfolk Southern Corp. announced that construction of an 8,000-mile transcontinental fiber-optic network, known as Fibertrak and originally scheduled for completion by 1987, was deferred because of difficulty in obtaining the customer commitments necessary to begin construction.[21] Teleconnect Co. and Williams Pipe Line Co. announced the construction of a 1,200-mile fiber-optic network linking Chicago, IL, to cities in six States. Construction of 85% of the line reportedly would involve pulling the cable through pipeline once used to transport liquid petroleum products. The project was scheduled to be completed in 1986.[22] US Telecom reported plans to construct a 23,000-mile fiber-optic network linking major U.S. cities from coast to coast.[23] Representatives of 22 telecommunications companies and agencies in 10 countries announced the approval of a draft agreement to construct and maintain the first fiber-optic undersea cable to span the Pacific Ocean. The system covering 7,200 nautical miles and connecting California, Hawaii, Japan, Guam, and the Philippines was expected to be completed by the end of 1988.[24]

Germanium was used as a substrate upon which gallium arsenide phosphide was deposited to form an essential part of light-emitting diodes. Germanium was also used in the manufacture of other semiconductor electronic equipment; to improve the hardness of aluminum, copper, and magnesium alloys; and, in some foreign countries, as a catalyst in the production of polyester fibers and plastic bottles.

## PRICES

The domestic producer prices, published in Metals Week, for germanium metal and germanium dioxide were unchanged throughout 1985 at $1,060 and $660 per kilogram, respectively. Competition from imported material reportedly resulted in some discounting by domestic producers.

## FOREIGN TRADE

A comparison of the value per kilogram of imported germanium material with the published foreign producer price for germanium metal was used to estimate the germanium content of imported scrap. In 1985, the estimated germanium content of total imports was calculated to be approximately 11,000 kilograms.

### Table 8.—U.S. imports for consumption of germanium, by class and country

| Class and country | 1984 Gross weight (kilograms) | 1984 Value | 1985 Gross weight (kilograms) | 1985 Value |
|---|---|---|---|---|
| Unwrought and waste and scrap: | | | | |
| Belgium-Luxembourg | 108,508 | $4,258,829 | 3,772 | $1,980,066 |
| Canada | 47 | 91,512 | 23 | 7,206 |
| China | -- | -- | 4,044 | 1,952,255 |
| Costa Rica | -- | -- | 1,000 | 597,643 |
| France | 3,600 | 1,493,087 | 1,227 | 722,304 |
| German Democratic Republic | -- | -- | 8 | 2,220 |
| Germany, Federal Republic of | 1,438 | 594,313 | 102 | 166,612 |
| Netherlands | 249 | 111,283 | 141 | 7,191 |
| Nigeria | -- | -- | 8 | 8,205 |
| Switzerland | -- | -- | 111 | 41,037 |
| U.S.S.R | -- | -- | 5 | 1,865 |
| United Kingdom | 1,432 | 230,977 | 611 | 242,226 |
| Total | 115,274 | 6,780,001 | 11,047 | 5,722,830 |
| Wrought: | | | | |
| Belgium-Luxembourg | 1,023 | 509,373 | 2,540 | 2,385,340 |
| Brazil | -- | -- | 249 | 307,609 |
| Canada | 1 | 745 | 9 | 5,625 |
| Germany, Federal Republic of | 133 | 34,411 | 5 | 4,624 |
| Norway | -- | -- | 180 | 72,661 |
| Singapore | 273 | 180,248 | 679 | 203,378 |
| Sweden | -- | -- | 182 | 126,492 |
| United Kingdom | 15 | 34,482 | -- | -- |
| Total | 1,445 | 759,259 | 3,794 | 3,105,729 |

Source: Bureau of the Census.

### Table 9.—U.S. import duties for germanium metal and germanium dioxide

| Item | TSUS No. | Most favored nation (MFN) Jan. 1, 1985 | Most favored nation (MFN) Jan. 1, 1987 | Non-MFN Jan. 1, 1985 |
|---|---|---|---|---|
| Germanium dioxide | 423.00 | 4.0% ad valorem | 3.7% ad valorem | 25% ad valorem. |
| Metal, unwrought and waste and scrap | 628.25 | do | do | Do. |
| Metal, wrought | 628.30 | 6.4% ad valorem | 5.5% ad valorem | 45% ad valorem. |

## WORLD REVIEW

World refinery production was estimated at 80,000 kilograms.[25] Germanium was produced by MHO, Belgium; Société Minière et Métallurgique de Penarroya S.A., France; Società Mineraria e Metallurgica di Pertusola S.A., Italy; Bleiberger Bergwerks-Union AG, Austria; and Preussag Metall AG, Federal Republic of Germany. Germanium refineries also were in China, Japan, and the U.S.S.R.

**Canada.**—Telecom Canada, a consortium of nine telephone companies and Telesat Canada, announced plans to build a nationwide system of single-mode fiber-optic cable to carry long-distance telephone traffic. The system reportedly would span 7,000 kilometers.[26]

**Finland.**—Outokumpu Oy announced the purchase of Princeton Gamma-Tech, Princeton, NJ, which specialized in the ultrahigh purification of germanium and the growing of germanium crystals.

**Japan.**—Germanium metal production in Japan reached 10,277 kilograms, an increase of 25% compared with 1984 production levels. Germanium dioxide production was reported to be 14,083 kilograms in 1985 compared with 10,872 kilograms in 1984.[27]

**Spain.**—The world's first repeatered underwater fiber-optic communications system for commercial use was installed in the Canary Islands off North Africa by the American Telephone & Telegraph Co. and Compañia Telefónica Nacional de España, the Spanish national telephone company. The 72-mile cable system linking Tenerife and Gran Canaria reportedly would be used initially as a testing system to confirm the design of two similar but much larger systems that were planned for completion in the near future, namely, a 3,000-mile transatlantic cable, known as TAT-8, running from New Jersey to the United Kingdom and France and a 7,200-mile system linking California, Hawaii, Japan, Guam, and the Philippines. Upon completion of testing, the system would be turned over to the Spanish national telephone company for commercial use.[28]

**Taiwan.**—Siecor Corp., Hickory, NC, reported the signing of an agreement with GTE Communications Systems to supply single-mode fiber-optic cable for installation in Taiwan. This project was reportedly the largest fiber-optic project Taiwan had undertaken and the first to use single-mode technology.

## TECHNOLOGY

A process was reportedly developed to recover unused germanium from effluents generated during the modified chemical vapor deposition process used to manufacture optical fibers. The process included a gas scrubber to incorporate the unreacted germanium into solution, a recirculation system to increase the germanium concentration in the solution, a reaction to form a germanium precipitate, and a filtration step to isolate the germanium-containing solids into a wet filter cake, which could be reprocessed to make germanium tetrachloride. The process reportedly was capable of recovering greater than 95% of the unreacted germanium.[29]

Sovonics Solar Systems, a joint venture of Energy Conversion Devices and Standard Oil Co. of Ohio, reported the development of a silicon-based amorphous alloy solar cell with an energy conversion efficiency of 12.2%. The 1-square-centimeter cell consisted of three vertically stacked subcells, each of which was sensitive to a different color in the solar spectrum. The subcells were made of a proprietary silicon material containing germanium, fluorine, and hydrogen.[30]

A method reportedly was developed for epitaxially growing high-quality thin films of germanium on sodium chloride substrates by plasma-enhanced chemical vapor deposition and then separating these germanium films by either melt-away or differential thermal shear stress techniques. The free-standing germanium films could be used as substrates for the growth of thin-film gallium arsenide solar cells. These solar cells could be used in large solar cell arrays for space applications because of their projected high power-to-weight ratio.[31]

# INDIUM[32]

Indium was produced by the Arconium Corp., Providence, RI, and Indium Corp. of America, Utica, NY. Domestic production in 1985 remained about the same as that of 1984, and imports maintained a significant market share. The Bureau of Mines does not publish domestic production data on indium. Small quantities of secondary indium were available from specialty metal recycling firms.

## CONSUMPTION AND USES

Indium usage remained about the same as that of 1984. Consumption in the categories of fusible alloys and solders remained strong. New indium solders were developed during the year. Consumption for nuclear control rods remained low, essentially at a replacement level. Research continued on a broad range of possible new applications, especially for solar cells and an indium-tin oxide coating for flat glass that would be transparent, electrically conductive, and prevent entry of infrared rays. Estimated consumption patterns for indium metal were electrical and electronic components, 40%; solders, alloys, and coating, 40%; and research and other uses, 20%.

## PRICES

The producer price of indium, published in Metals Week, was $3.10 per troy ounce at the beginning of the year, lowered to $2.80 per troy ounce in February, and then lowered to $2.50 per troy ounce in March, at which price level it remained for the duration of the year.

## FOREIGN TRADE

Imports of indium declined slightly but remained at the relatively high levels of recent years. Italy was the leading supplier in 1985, followed by France, the United Kingdom, and China.

### Table 10.—U.S. imports for consumption of indium, by class and country

(Thousand troy ounces and thousand dollars)

| Class and country | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity | Value | Quantity | Value | Quantity | Value |
| Unwrought and waste and scrap: |  |  |  |  |  |  |
| Belgium-Luxembourg | 218 | 556 | 263 | 837 | 99 | 257 |
| Canada | 33 | 135 | 26 | 96 | 16 | 100 |
| China | ([1]) | 10 | 7 | 19 | 128 | 423 |
| France | 278 | 521 | 231 | 844 | 140 | 308 |
| Germany, Federal Republic of | ([1]) | 1 | 13 | 43 | 2 | 30 |
| Hong Kong | ([1]) | 12 | -- | -- | 19 | 50 |
| Italy | 250 | 435 | 101 | 207 | 259 | 596 |
| Jamaica | -- | -- | -- | -- | ([1]) | 17 |
| Japan | 3 | 24 | 9 | 40 | 2 | 43 |
| Netherlands | 16 | 37 | 78 | 242 | 16 | 67 |
| Peru | 49 | 129 | 84 | 273 | 111 | 260 |
| Switzerland | 32 | 77 | 56 | 125 | 16 | 36 |
| Taiwan | -- | -- | 8 | 42 | -- | -- |
| Tunisia | -- | -- | 6 | 19 | -- | -- |
| United Kingdom | 182 | 780 | 130 | 1,575 | 147 | 1,009 |
| Total[2] | 1,071 | 2,719 | 1,015 | 4,365 | 955 | 3,197 |
| Wrought: |  |  |  |  |  |  |
| Belgium-Luxembourg | -- | -- | -- | -- | ([1]) | 6 |
| Canada | -- | -- | ([1]) | 62 | -- | -- |
| France | -- | -- | -- | -- | 19 | 90 |
| Germany, Federal Republic of | ([1]) | 1 | ([1]) | 1 | ([1]) | 3 |
| Hong Kong | ([1]) | 5 | -- | -- | -- | -- |
| Japan | 1 | 11 | 2 | 40 | 3 | 60 |
| United Kingdom | 1 | 59 | 4 | 104 | 3 | 124 |
| Other | -- | -- | 1 | 5 | -- | -- |
| Total | 2 | 76 | 7 | 212 | 25 | 283 |

[1] Less than 1/2 unit.

[2] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

### Table 11.—U.S. import duties for indium

| Item | TSUS No. | Most favored nation (MFN) |  | Non-MFN |
|---|---|---|---|---|
|  |  | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Unwrought, waste, and scrap | 628.45 | 0.6% ad valorem | Free | 25% ad valorem. |
| Wrought indium | 628.50 | 5.0% ad valorem | 3.6% ad valorem | 45% ad valorem. |
| Indium compounds | 423.96 | 1.2% ad valorem | Free | 25% ad valorem. |

### WORLD REVIEW

World production remained about the same as that of 1984. Major world refiners included Cominco in Canada, MHO in Belgium, Penarroya in France, Nippon Mining Co. Ltd. in Japan, Minero Perú Comercial in Peru, and Mining and Chemical Products Ltd. in the United Kingdom.

## RHENIUM[33]

Rhenium was processed by two domestic firms in 1985. Consumption of rhenium increased an estimated 27% over that of 1984 to 13,000 pounds. Imports increased from 6,716 pounds (revised) in 1984 to 8,268 pounds in 1985. The major use continued to be bimetallic platinum-rhenium catalysts to produce low-lead and lead-free gasoline. The price of rhenium was level throughout the year, at $300 per pound for the metal and $200 per pound for ammonium perrhenate.

**Domestic Data Coverage.**—Domestic mine production data for byproduct rhenium are developed by the Bureau of Mines from a single voluntary survey of U.S. porphyry-copper-molybdenum operations. Of the 18 operations to which a survey request was made, all responded, representing 100% of the total production shown in table 12.

**Table 12.—Salient U.S. rhenium statistics**

(Pounds of contained rhenium)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Mine production[1] | 15,800 | 11,200 | 8,100 | 8,600 | 10,500 |
| Recovered[2] | W | W | W | W | W |
| Consumption[e] | 6,600 | 5,900 | 8,800 | 10,200 | 13,000 |
| Imports (metal) | 580 | 176 | 623 | 1,962 | 4,943 |
| Imports for consumption of ammonium perrhenate | 9,089 | 5,193 | 5,947 | [r]4,754 | 3,325 |
| Stocks, Dec. 31 | W | W | W | W | W |

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Calculated rhenium contained in $MoS_2$ concentrates.

[2]In prior years, this was shown as mine production.

### DOMESTIC PRODUCTION

Rhenium is contained in molybdenite ($MoS_2$) concentrates, which are produced as a byproduct of porphyry copper ores from seven mines in the Southwestern United States. Mine production in table 12 was calculated to be the rhenium content of $MoS_2$ concentrates.

Duval Corp. was the only domestic producer to recover rhenium in 1985.

### CONSUMPTION AND USES

Domestic consumption of rhenium increased an estimated 27% over that of 1984 to 13,000 pounds. The increase in consumption was due to the increase in the manufacturing of catalysts for the petroleum industry. Platinum-rhenium bimetallic reforming catalysts are used by the petroleum industry to produce low-lead and lead-free high-octane gasoline. These catalysts compete with monometallic platinum catalysts and with other bimetallic catalysts that are used in the reforming process. Although the rhenium content ranges from 0.25% to 0.9% by weight, the majority of these catalysts contain 0.3% rhenium and 0.3% platinum, using alumina as the support medium.

Of the three basic types of bimetallic reforming catalysts, the semiregenerative type accounted for about 60% of the total reforming capacity in 1985. This type of catalyst requires process shutdown for regeneration at specified intervals. Cyclic and other types (nonregenerative, continuous, and moving-bed systems) accounted for 10% and 9%, respectively, of the total reforming capacity. An estimated 80% of the total reforming capacity employed platinum-rhenium catalysts. Other applications of reforming platinum-rhenium catalysts included the production of benzene, toluene, and xylenes.

About 10% of the total consumption of rhenium was used in the form of powder or alloys. The major portion of rhenium used in these forms was contained in tungsten-rhenium and molybdenum-rhenium alloys. When alloyed with other metals, rhenium improves their mechanical and electrical properties, acid and heat resistance, wear and corrosion resistance, and durability. Rhenium was used in manufacturing thermocouples, ionization gauges, electron tubes and targets, metallic coatings, semiconductors, heating elements, high-temperature nickel-based alloys, vacuum tubes, mass spectrographs, and electromagnets.

## PRICES

The price of rhenium remained level during the year. The price of ammonium perrhenate was $200 per pound, and the average price of rhenium metal was about $300 per pound.

## FOREIGN TRADE

U.S. imports for consumption of rhenium totaled 8,268 pounds, an increase of 23% over that of 1984. Ammonium perrhenate imports totaled 3,325 pounds of metal content. This represented a 30% decrease from that of 1984. The value of ammonium perrhenate imports was about $0.7 million. About 88% of the imports of ammonium perrhenate originated from Chile and 12% from the Federal Republic of Germany. Imports of rhenium metal totaled 4,943 pounds, which represented a 152% increase over that of 1984. The value of these imports totaled $1.2 million.

### Table 13.—U.S. import duties for rhenium materials

| Item | TSUS No. | Most favored nation (MFN) | | Non-MFN |
|---|---|---|---|---|
| | | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Unwrought metal | 628.9000 | 4.0% ad valorem | 3.7% ad valorem | 25% ad valorem. |
| Wrought metal | 628.9500 | 6.4% ad valorem | 5.5% ad valorem | 45% ad valorem. |
| Ammonium perrhenate | 417.4420 | 3.3% ad valorem | 3.1% ad valorem | 25% ad valorem. |
| Perrhenic acid | 416.4540 | 4.7% ad valorem | 4.2% ad valorem | 25% ad valorem. |

### Table 14.—U.S. imports for consumption of ammonium perrhenate, by country

(Rhenium content)

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (pounds) | Value (thousands) | Quantity[r] (pounds) | Value (thousands) | Quantity (pounds) | Value (thousands) |
| Chile | 4,057 | $712 | 3,379 | $740 | 2,918 | $611 |
| Germany, Federal Republic of | 1,890 | 419 | 564 | 131 | 407 | 58 |
| Italy | -- | -- | 811 | 181 | -- | -- |
| Total | 5,947 | 1,131 | 4,754 | 1,052 | 3,325 | 669 |

[r] Revised.

Source: Bureau of the Census.

### Table 15.—U.S. imports for consumption of rhenium metal, by country

| Country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Gross weight (pounds) | Value | Gross weight (pounds) | Value | Gross weight (pounds) | Value |
| Chile | -- | -- | -- | -- | 3,300 | $825,000 |
| France | -- | -- | 2 | $920 | -- | -- |
| Germany, Federal Republic of | 618 | $174,000 | 1,836 | 423,032 | 1,424 | 337,662 |
| Italy | -- | -- | 100 | 19,500 | -- | -- |
| United Kingdom | -- | -- | 2 | 417 | 193 | 54,065 |
| Other[1] | 10 | 6,000 | 22 | 5,590 | 26 | 8,378 |
| Total | 623 | 180,000 | 1,962 | 449,459 | 4,943 | 1,225,105 |

[1] Includes Haiti, Sweden, and Switzerland.

Source: Bureau of the Census.

### WORLD REVIEW

World production of rhenium was estimated to be 30,000 pounds, exclusive of U.S. production. Rhenium was recovered from byproduct $MoS_2$ concentrates from porphyry copper deposits in Canada, Chile, Iran, Peru, the U.S.S.R., and the United States. In addition, the U.S.S.R. also recovered rhenium as a byproduct from the Dzhezkazgan sedimentary copper deposit in Kazakhstan. Rhenium metal and compounds were recovered from molybdenum concentrates in Chile, France, the Federal Republic of Germany, Sweden, the U.S.S.R., the United Kingdom, and the United States.

**Canada.**—The Island Copper Mine in British Columbia continued to be the sole producer of rhenium in Canada. $MoS_2$ concentrates, which contained approximately 7,700 pounds of rhenium, were exported.

**Chile.**—Chilean recovery of rhenium was estimated at 8,700 pounds, the largest amount produced by a market economy country.

## SCANDIUM[34]

Domestic production and consumption of scandium were estimated to be higher than in 1984. Increased demand for scandium used in laser applications was reportedly responsible for the higher levels of production. Special-use light bulbs and high-energy laser crystals continued to be the major markets for scandium. Scandium was obtained as a byproduct from processing mine tailings at three domestic locations in the Western United States. The principal mine source closed its operations in August 1985.

**Domestic Data Coverage.**—Domestic production data for scandium are estimated by the Bureau of Mines based on discussions with domestic producers and processors.

### DOMESTIC PRODUCTION

Three mines provided scandium concentrates for refining during the year. Concentrates were obtained as a byproduct of processing copper tailings for uranium by Westinghouse Electric Corp., Bingham Canyon, UT. Westinghouse closed its Bingham Canyon, UT, operations in August as a result of weak prices for uranium. Reportedly, Westinghouse was attempting to locate a purchaser for its uranium-scandium extraction plant. Scandium was also recovered as a byproduct of processing residual fluorite screenings for the scandium mineral thortveitite, previously mined at Crystal Mountain, MT, and from byproduct scandium-bearing tungsten concentrates derived from processing molybdenum ores at the Climax Mine, Climax, CO.

Refined scandium products were produced by Baldwin Metal Processing Co., Phoenix, AZ; Boulder Scientific Co., Mead, CO; Research Chemicals Div. of NUCOR Corp., Phoenix, AZ; and Sausville Chemical Co. Inc., Garfield, NJ.

### CONSUMPTION AND USES

The apparent consumption of scandium in 1985 was estimated at 150 kilograms of equivalent scandium oxide. The major end use was in high-energy laser crystals of gadolinium-scandium-gallium garnets (GSGG) doped with chromium and neodymium; scandium accounts for up to 30% by weight of the crystal. The GSGG lasing medium is reportedly twice as efficient as yttrium-aluminum garnets with neodymium (Nd:YAG). Laser applications for GSGG are in communications and fusion research.

Scandium is used in high-intensity mercury vapor lights to produce a highly efficient, near-sunlight color emission that is important for indoor and nighttime color television transmission. Approximately 3 to 5 milligrams of scandium are added per bulb.

The radioactive isotope scandium-46 was used as a tracing agent in petroleum cracking refineries, in crude oil reservoirs during secondary recovery, and in oil wells after cementing and fracturing.

Small amounts of scandium metal were reportedly used in semiconductors, while minor amounts of the compound found use in petroleum catalyst reactions.

Additions of scandium carbide to titanium carbide reportedly create a binary carbide with a hardness close to that of diamond.

### PRICES

No published prices were available for scandium. The yearend nominal prices, compiled by the Bureau of Mines based on information from several suppliers, for scandium oxide per kilogram were as follows: 95% purity, $6,800; 98% purity,

$7,400; 99.0% purity, $8,000; 99.9% purity, $9,000; 99.99% purity, $15,000; and 99.999% purity, $25,000. Scandium metal prices varied considerably depending on purity and amount.

### FOREIGN TRADE

No trade data were available for scandium on an individual basis. Foreign countries reportedly producing scandium include China, France, and the U.S.S.R. The U.S.S.R. has historically been a major source of imported high-purity scandium oxide.

### TECHNOLOGY

Researchers at NV Philips Corp., Eindhoven, Netherlands, developed a dual-anode tube using scandium and molybdenum or scandium and tungsten for improved detection of elements in X-ray fluorescence spectrometry. The anode is in the form of a thin layer of the light-element material scandium, deposited on a heavy-element base, molybdenum or tungsten. The new tube allows lower voltage excitation of X-rays from the scandium surface layer, while higher energy excitation penetrates to the underlying heavy-element material before radiating. Scandium is used because its excitation efficiency in detection of light elements up to titanium is twice that of the commonly used chromium tube.[35]

A sodium-scandium-phosphate compound, known as foskan, named from the three Russian words for the elements, is being studied in the U.S.S.R. The binary phosphate and its analogs exhibit several interesting properties, including a high fusion temperature, ferroelectricity, and high ion conductivity. Research showed that the high ion conductivity can be applied in sodium-sulfur storage batteries where sodium and sulfur are molten electrodes and the scandium-bearing binary phosphate functions as a thin ceramic membrane electrolyte. Foskan's three-dimensional open structure allows the small sodium cations to travel freely through the voids formed by interconnected omnidirectional conductivity channels. At temperatures above 166° C, the sodium cations flow freely creating a super ion exchanger electrolyte for use in the sodium-sulfur batteries. Battery energy capacities using this system are reportedly an order of magnitude higher than lead storage batteries.[36]

## SELENIUM[37]

One of the four U.S. copper refineries with capacity for production of byproduct selenium did not produce any of the metal in 1985, and another discontinued its operations in the third quarter; therefore, domestic production decreased significantly. Consumption also declined and net imports fell slightly, while producers' stocks increased substantially.

**Domestic Data Coverage.**—Domestic data for selenium are developed by the Bureau of Mines from a voluntary survey of U.S. operations. The three domestic refiners of selenium responded to a survey of their stocks, primary refined production, and shipments of selenium to consumers. Data are withheld to avoid disclosing company proprietary data.

**Table 16.—Salient selenium statistics**

(Kilograms of contained selenium unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production, primary refined | 251,949 | 242,996 | 353,860 | [p]253,598 | W |
| Shipments to consumers | 207,854 | 307,610 | 374,030 | 224,401 | W |
| Exports, metal, waste and scrap | 60,523 | 117,267 | 93,368 | 122,929 | 154,122 |
| Imports for consumption | 311,566 | 347,329 | 297,029 | 376,946 | 400,658 |
| Apparent consumption | 458,898 | 537,672 | 577,691 | 478,418 | W |
| Stocks, yearend, producer[1] | 292,558 | 254,210 | 152,790 | 139,159 | W |
| Dealers' price, average per pound, commercial-grade[2] | $4.38 | $3.53 | $3.87 | $9.02 | $6.00-$10.25 |
| World: Refinery production | [r]1,285,238 | [r]1,132,495 | 1,325,031 | [p]1,350,702 | [e]1,122,835 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Granular selenium, a semirefined form of selenium, is included in stocks.

[2]Metals Week.

## DOMESTIC PRODUCTION

Most primary selenium was recovered from anode slimes generated in the electrolytic refining of copper. Selenium also was believed to have been recovered from lead slimes and nonferrous flue dusts.

Primary selenium was recovered from both domestic and imported materials at three U.S. copper refineries: Asarco at Amarillo, TX; Kennecott at Magna, UT; and Phelps Dodge Refining Corp. at El Paso, TX. Production at the Kennecott refinery was discontinued during the year owing to the cessation of copper mining in Utah. Selenium-bearing copper slimes from other domestic copper refiners were either shipped to the above refineries or exported for processing.

High-purity selenium metal and various selenium compounds were produced from commercial-grade metal by the three copper refineries and other processors.

Scrap xerographic materials containing selenium were exported to Canada and the United Kingdom for processing to recover selenium.

## CONSUMPTION AND USES

Apparent consumption of refined selenium decreased from the 1984 level in all major end uses. Estimated consumption of selenium by end-use category was electronic and photocopier components, 35%; glass manufacturing, 30%; pigment and chemicals, 25%; and other, including metallurgy and agriculture, 10%.

The major electronic use of selenium was as a photoreceptor in plain paper electrophotographic copiers.

The U.S. automobile and construction industries contributed to a strong demand for selenium-containing pigments. The pigments, which range in color from light orange to maroon, depending on the selenium content, have good heat stability and are important colorants for plastics, glass, and ceramics. The primary use of selenium in the glass industry in 1985 was in container glass, where it was used to decolor the yellow-green tint imparted by ferrous ions. Also, selenium was used in architectural plate glass, where it was used in combination with cobalt oxide and iron oxide to reduce solar heat transmission.

## PRICES

Standard commercial-grade selenium averaging 99.5% selenium was sold as powder, available in several mesh sizes or as small lumps or shot. High-purity selenium containing 99.99% selenium or better was marketed as pellets or sticks. Specifications for pigment-grade selenium powder generally required a selenium content of 99.8%. Other forms of selenium available included selenium dioxide, ferroselenium, sodium selenite, and sodium selenate.

The New York dealer price for commercial-grade selenium, quoted by Metals Week on a daily basis, ranged from $6.00 to $10.25 per pound.

## FOREIGN TRADE

Exports increased to a record-high level of 154,122 kilograms. In 1985, the United Kingdom was the recipient of about one-third of the exported selenium materials, primarily scrap. Exports to Mexico and the Philippines accounted for most of the increased exports.

Imports of selenium were the highest since the peak year of 1975, when 403,000 kilograms of selenium was imported. Canada continued to be the largest supplier of imported selenium metal. Belgium-Luxembourg, Japan, and the United Kingdom were the other major import sources. Approximately 75,000 kilograms of the imported refined selenium, primarily from the United Kingdom, was recovered from scrap that had been exported from the United States for processing.

## Table 17.—U.S. exports of selenium metal, waste and scrap, by country

| Country | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity (kilograms of contained selenium) | Value | Quantity (kilograms of contained selenium) | Value | Quantity (kilograms of contained selenium) | Value |
| Argentina | -- | -- | 1,089 | $10,200 | 1,179 | $22,750 |
| Australia | 2,211 | $19,941 | -- | -- | 962 | 29,220 |
| Belgium-Luxembourg | 1,611 | 24,049 | 322 | 5,141 | -- | -- |
| Brazil | -- | -- | 254 | 8,100 | 650 | 10,400 |
| Canada | 1,448 | 23,146 | 2,462 | 39,365 | 2,207 | 40,595 |
| Chile | -- | -- | 5,517 | 24,313 | -- | -- |
| Colombia | 250 | 2,163 | 7,831 | 198,864 | 894 | 22,660 |
| France | -- | -- | 1,758 | 38,173 | 318 | 5,075 |
| Germany, Federal Republic of | 1,996 | 17,600 | 18,769 | 139,418 | 7,861 | 126,793 |
| India | 41 | 655 | -- | -- | 68 | 4,765 |
| Ireland | 8,375 | 24,955 | -- | -- | -- | -- |
| Italy | -- | -- | -- | -- | 1,456 | 29,015 |
| Jamaica | 100 | 1,488 | 91 | 3,000 | -- | -- |
| Japan | 10,048 | 75,287 | 27,255 | 186,992 | 36,951 | 289,592 |
| Korea, Republic of | -- | -- | -- | -- | 45 | 1,800 |
| Mexico | 9,979 | 97,010 | 1,799 | 28,750 | 19,265 | 308,481 |
| Netherlands | 8,052 | 64,368 | 6,822 | 82,744 | 7,711 | 106,360 |
| Norway | -- | -- | -- | -- | 236 | 6,760 |
| Philippines | 292 | 6,458 | -- | -- | 18,144 | 42,000 |
| Portugal | 635 | 4,810 | -- | -- | 91 | 1,950 |
| Switzerland | 1,996 | 15,400 | 7,983 | 71,060 | 4,990 | 75,350 |
| Thailand | -- | -- | 499 | 11,000 | -- | -- |
| United Kingdom | 46,334 | 393,801 | 45,480 | 739,450 | 51,096 | 316,177 |
| Total[1] | 93,368 | 771,131 | 122,929 | 1,586,565 | 154,122 | 1,439,743 |

[1] Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

## Table 18.—U.S. imports for consumption of selenium, by class and country

| Class and country | 1983 |  | 1984 |  | 1985 |  |
|---|---|---|---|---|---|---|
|  | Quantity (kilograms of contained selenium) | Value | Quantity (kilograms of contained selenium) | Value | Quantity (kilograms of contained selenium) | Value |
| Unwrought and waste and scrap: |  |  |  |  |  |  |
| Belgium-Luxembourg | 34,643 | $930,511 | 47,483 | $1,084,424 | 63,353 | $1,572,220 |
| Canada | 84,602 | 1,679,022 | 130,317 | 2,786,063 | 111,927 | 2,352,429 |
| Chile | -- | -- | 3,498 | 64,015 | 7,500 | 158,902 |
| German Democratic Republic | -- | -- | -- | -- | 45 | 14,743 |
| Germany, Federal Republic of | 20,901 | 378,958 | 23,364 | 402,088 | 5,550 | 126,877 |
| Japan | 54,651 | 1,340,519 | 46,074 | 1,904,155 | 72,609 | 2,056,694 |
| Netherlands | -- | -- | 2,755 | 64,610 | 15,239 | 30,851 |
| Peru | 8,941 | 66,313 | 2,994 | 32,605 | -- | -- |
| Philippines | -- | -- | 5,000 | 59,525 | 16,748 | 243,747 |
| Sweden | 853 | 27,096 | 1,032 | 26,258 | 100 | 3,750 |
| Taiwan | 1,100 | 8,036 | -- | -- | -- | -- |
| United Kingdom | 65,378 | 997,809 | 80,844 | 964,306 | 66,434 | 910,947 |
| Total | 271,064 | 5,423,259 | 343,361 | 7,388,049 | 359,505 | 7,467,160 |
| Selenium dioxide: |  |  |  |  |  |  |
| Belgium-Luxembourg | -- | -- | 35 | 529 | -- | -- |
| Germany, Federal Republic of | 4,437 | 69,285 | 5,598 | 121,704 | 6,916 | 164,471 |
| Sweden | 142 | 10,514 | 71 | 4,500 | -- | -- |
| United Kingdom | -- | -- | 29 | 1,586 | -- | -- |
| Total | 4,579 | 79,799 | 5,733 | 128,319 | 6,916 | 164,471 |
| Selenium salts: |  |  |  |  |  |  |
| Belgium-Luxembourg | -- | -- | -- | -- | 567 | 29,839 |
| France | -- | -- | 6,399 | 6,397 | -- | -- |
| Japan | 603 | 5,596 | -- | -- | -- | -- |
| Korea, Republic of | 5,168 | 8,524 | 4,429 | 6,197 | 4,847 | 4,962 |
| Taiwan | -- | -- | 50 | 400 | -- | -- |
| United Kingdom | 150 | 8,550 | 193 | 6,821 | 7,000 | 114,959 |
| Total | 5,921 | 22,670 | 11,071 | 19,815 | 12,414 | 149,760 |

### Table 18.—U.S. imports for consumption of selenium, by class and country —Continued

| Class and country | 1983 Quantity (kilograms of contained selenium) | 1983 Value | 1984 Quantity (kilograms of contained selenium) | 1984 Value | 1985 Quantity (kilograms of contained selenium) | 1985 Value |
|---|---|---|---|---|---|---|
| Sodium selenite: | | | | | | |
| Canada | 841 | $36,794 | 460 | $17,223 | 42 | $2,090 |
| Germany, Federal Republic of | 10,090 | 257,357 | 1,154 | 28,745 | 3,013 | 80,091 |
| Japan | -- | -- | 450 | 29,592 | 1,058 | 29,575 |
| Spain | -- | -- | 1,150 | 20,939 | -- | -- |
| Sweden | 230 | 4,128 | -- | -- | -- | -- |
| United Kingdom | 3,801 | 77,975 | 9,968 | 249,974 | 13,835 | 332,551 |
| Total | 14,962 | 376,254 | 13,182 | 346,473 | 17,948 | 444,307 |
| Other selenium compounds: | | | | | | |
| Canada | -- | -- | -- | -- | 1,105 | 3,394 |
| Germany, Federal Republic of | -- | -- | 13 | 1,548 | 22 | 1,443 |
| Japan | 25 | 1,735 | 2,574 | 133,671 | 1,588 | 81,559 |
| Netherlands | -- | -- | 42 | 482 | -- | -- |
| Sweden | -- | -- | 170 | 2,107 | 123 | 1,398 |
| United Kingdom | 478 | 18,208 | 800 | 33,400 | 1,037 | 44,072 |
| Total | 503 | 19,943 | 3,599 | 171,208 | 3,875 | 131,866 |
| Grand total | 297,029 | 5,921,925 | 376,946 | 8,053,864 | 400,658 | 8,357,564 |

Source: Bureau of the Census; figures adjusted by Bureau of Mines.

### Table 19.—U.S. import duties for selenium

| Item | TSUS No. | Most favored nation (MFN) Jan. 1, 1985 | Most favored nation (MFN) Jan. 1, 1987 | Non-MFN Jan. 1, 1985 |
|---|---|---|---|---|
| Selenium metal | 632.40 | Free | Free | Free. |
| Selenium dioxide and salts | 420.50,<br>420.52 | do | do | Do. |
| Sodium selenite and other selenium compounds | 421.625,<br>420.54 | 4.0% ad valorem. | 3.7% ad valorem. | 25% ad valorem. |

## WORLD REVIEW

Estimated world refinery production of selenium was about the same as that of 1984 and was slightly higher than the estimated world demand of about 1,100 tons.

### Table 20.—Selenium: World refinery production, by country[1]

(Kilograms of contained selenium)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Belgium[e] | 60,000 | 60,000 | 60,000 | 60,000 | 60,000 |
| Canada[3] | 350,010 | [r]222,000 | 266,000 | [r] [e]354,000 | 350,000 |
| Chile | 33,665 | 23,011 | 43,869 | 25,450 | 25,000 |
| Finland | [r]19,422 | 10,020 | 11,172 | 16,975 | 17,000 |
| India | 4,104 | 5,351 | 3,684 | [e]4,000 | 4,000 |
| Japan | 428,081 | 410,490 | 433,122 | 464,524 | [4]496,835 |
| Mexico | 12,000 | 29,000 | 24,000 | 44,000 | 40,000 |
| Peru | 22,478 | 20,851 | 19,553 | 20,800 | 22,000 |
| Sweden[e] | [4]44,000 | 44,000 | 44,000 | 45,000 | 45,000 |
| United States | 251,949 | 242,996 | 353,860 | 253,598 | W |
| Yugoslavia | 35,600 | 42,323 | 43,720 | [e]45,000 | 46,000 |
| Zambia[5] | 23,929 | 22,453 | 22,051 | 17,355 | 17,000 |
| Total | [r]1,285,238 | [r]1,132,495 | 1,325,031 | 1,350,702 | 1,122,835 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

[1]Insofar as possible, data relate to refinery output only; thus, countries that produced selenium contained in copper ores, copper concentrates, blister copper, and/or refinery residues, but did not recover refined selenium from these materials indigenously, were excluded to avoid double counting. Table includes data available through June 10, 1986.

[2]In addition to the countries listed, Australia, the Federal Republic of Germany, and the U.S.S.R. produced refined selenium, but output is not reported, and available information is inadequate for formulation of reliable estimates of output levels. Australia is known to produce selenium in intermediate metallurgical products and has facilities to produce elemental selenium. In addition to having facilities for processing imported anode slimes for the recovery of selenium and precious metals, the United Kingdom has facilities for processing selenium scrap.

[3]Refinery output from all sources, including imported materials and secondary sources.

[4]Reported figure.

[5]Data for fiscal year ending Mar. 31. In addition to refined selenium produced, Zambia exported significant quantities of selenium contained in anode slimes.

## TELLURIUM[38]

Domestic consumption, imports, and production decreased from the 1984 levels. Decreased consumption resulted in a slight decrease in prices. Estimated world refinery production was essentially the same as the 1984 level.

**Domestic Data Coverage.**—Domestic tellurium refinery production data were obtained from the only domestic producer on a voluntary survey form. Data are withheld to avoid disclosing company proprietary data.

### Table 21.—Salient U.S. tellurium statistics[1]

(Kilograms of contained tellurium unless otherwise specified)

| | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|
| Refinery production | W | W | W | W | W |
| Shipments to consumers | W | W | W | W | W |
| Imports for consumption | 37,953 | 16,602 | 11,829 | [r]35,383 | 30,050 |
| Apparent consumption | 85,202 | 45,978 | 56,639 | 107,311 | W |
| Stocks, yearend, producer | W | W | W | W | W |
| Producers' price, per pound, yearend, commercial grade | $14.00 | $10.00 | $9.00 | $11.00-$11.50 | $10.00 |

[r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]World refinery production for selected countries is given in table 24.

### DOMESTIC PRODUCTION

Commercial-grade tellurium was recovered by Asarco, at Amarillo, TX, from copper anode slimes, a byproduct of electrolytic copper refining.

High-purity tellurium, tellurium master alloys, and tellurium compounds were produced by primary and intermediate processors from commercial-grade metal and tellurium dioxide.

### CONSUMPTION AND USES

Estimated consumption of tellurium by end use was iron and steel products, 60%; nonferrous metal, 25%; chemicals, including rubber manufacturing, 10%; and other, including xerographic and electronic applications, 5%.

The principal end use of tellurium was as an alloying metal in the production of free-machining steels and free-machining copper alloys. The addition of up to 0.1% tellurium improves the machinability of steels; the addition of tellurium to copper alloys improves their corrosion resistance as well as their machinability.

Tellurium catalysts are used chiefly for the oxidation of a number of organic compounds, and to a lesser extent, for the hydrogenation of oils, and in chlorination and dehydrochlorination processes. Telluride salts can be used as an antioxidant in counteracting the formation of sludge in lubricating oils. Other tellurium compounds are used in germicides and fungicides and in the treatment of dermatitis. Tellurium has use as a glass former in combination with other metal oxides, as a color additive in metal-finishing operations, and in time-delay explosive detonators. Photoconductive mercury-cadmium-tellurium is the most widely used infrared sensing material for thermal imaging devices used in applications such as night vision and navigation systems. Such applications require detector-grade (99.99999%-pure) tellurium.

## PRICES

With decreased consumption, prices for commercial-grade tellurium decreased slightly from the 1984 level. The price for commercial-grade tellurium quoted by Asarco was $10.00 per pound at yearend. Commercial grades of tellurium metal, containing a minimum of 99% or 99.5% tellurium, are marketed as minus 200-mesh powder, 1-pound ingots, or 5-pound slabs. Tellurium dioxide is sold as powder ranging from minus 40-mesh to minus 200-mesh and containing a minimum of 75% tellurium.

## FOREIGN TRADE

Data on tellurium exports are not available. Canada was the major import source in 1985, accounting for 45% of total imports.

### Table 22.—U.S. imports for consumption of tellurium, by class and country

| Class and country | 1983 | | 1984 | | 1985 | |
|---|---|---|---|---|---|---|
| | Quantity (kilograms of contained tellurium) | Value | Quantity (kilograms of contained tellurium) | Value | Quantity (kilograms of contained tellurium) | Value |
| **Unwrought and waste and scrap:** | | | | | | |
| Belgium-Luxembourg | 992 | $17,870 | 4,003 | $68,764 | 5 | $5,978 |
| Canada | 9,461 | 540,080 | 20,382 | 369,745 | 13,458 | 453,929 |
| Germany, Federal Republic of | 2 | 343 | 1,019 | 17,367 | 5 | 1,404 |
| Japan | 95 | 5,574 | 1,825 | 103,338 | 499 | 29,063 |
| Netherlands | -- | -- | 1,300 | 23,884 | 500 | 9,653 |
| Peru | -- | -- | -- | -- | 963 | 18,963 |
| U.S.S.R | 9 | 10,500 | -- | -- | -- | -- |
| United Kingdom | 1,001 | 27,419 | 5,892 | 105,026 | 4,999 | 107,398 |
| Total | 11,560 | 601,786 | 34,421 | 688,124 | 20,429 | 626,308 |
| **Compounds:** | | | | | | |
| Belgium-Luxembourg | -- | -- | 724 | 21,112 | 726 | 15,391 |
| Canada | 215 | 5,533 | 200 | 5,753 | 73 | 1,904 |
| Germany, Federal Republic of | 4 | 1,378 | 23 | 3,408 | 51 | 3,369 |
| Japan | (1) | 887 | -- | -- | 82 | 10,900 |
| Philippines | -- | -- | -- | -- | 7,376 | 202,463 |
| United Kingdom | 50 | 12,064 | 14 | 6,572 | 17 | 5,536 |
| Total | 269 | 19,862 | 961 | 36,845 | 8,325 | 239,573 |
| **Salts:** | | | | | | |
| Germany, Federal Republic of | -- | -- | 1 | 270 | -- | -- |
| Netherlands | -- | -- | -- | -- | 1,296 | 5,410 |
| Total | -- | -- | 1 | 270 | 1,296 | 5,410 |
| Grand total | 11,829 | 621,648 | [r]35,383 | [r]725,239 | 30,050 | 871,291 |

[r] Revised.

[1] Less than 1/2 unit.

Source: Bureau of the Census.

### Table 23.—U.S. import duties for tellurium

| Item | TSUS No. | Most favored nation (MFN) | | Non-MFN |
|---|---|---|---|---|
| | | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Tellurium metal | 632.48 | 1.5% ad valorem | Free | 2.5% ad valorem. |
| Tellurium compounds and salts. | 421.90, 427.12 | 4.2% ad valorem | 3.7% ad valorem | Do. |

### WORLD REVIEW

Estimated refinery production of tellurium outside of the United States remained about the same as 1984 levels at 100 tons.

### Table 24.—Tellurium: World refinery production, by country[1]

(Kilograms of contained tellurium)

| Country[2] | 1981 | 1982 | 1983 | 1984[p] | 1985[e] |
|---|---|---|---|---|---|
| Canada[3] | 21,297 | [r]18,000 | 16,000 | [r][e]21,000 | 20,000 |
| India | [4]220 | (5) | (5) | (5) | -- |
| Japan | 61,700 | 62,800 | 54,800 | 64,500 | 63,000 |
| Peru | 21,310 | 20,726 | 15,116 | 14,094 | 15,500 |
| United States | W | W | W | W | W |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1] Insofar as possible, data relate to refinery output only; thus, countries that produced tellurium contained in copper ores, copper concentrates, blister copper, and/or refinery residues, but did not recover refined tellurium, are excluded to avoid double counting. Table is not totaled because of the exclusion of data from major world producers, notably the U.S.S.R. and the United States. Table includes data available through June 10, 1986.

[2] In addition to the countries listed, Australia, Belgium, the Federal Republic of Germany, and the U.S.S.R. are known to produce refined tellurium, but output is not reported, and available information is inadequate for formulation of reliable estimates of output levels. Moreover, the other major copper-refining nations such as Chile and Zambia may produce refined tellurium, but output in these nations is conjectural.

[3] Refinery output from all sources, including imports and secondary sources.

[4] Pilot plant production.

[5] Revised to zero.

## THALLIUM[39]

Although thallium was contained in ores mined in the United States, it was not recovered domestically as a marketable product in 1985. In other countries, thallium was recovered as a byproduct from flue dusts and residues collected in the smelting of copper, zinc, and lead ores. Domestic requirements for thallium were met by imports and withdrawals from stocks.

**Legislation and Government Programs.**—Thallium was considered to be a toxic material and was controlled to prevent a threat to the environment or labor force. In 1985, the EPA issued interim guidelines to assist local communities in establishing programs to respond to accidental releases of acutely toxic chemicals. Six thallium compounds were among the 402 chemicals identified as acutely hazardous. A chemical profile outlining the chemical and physical properties, health hazards, and precautions for safe handling and use was provided for each chemical listed.[40]

### CONSUMPTION AND USES

Based on import data, the domestic consumption of thallium was estimated to be 2,300 pounds in 1985. The uses of thallium included gamma radiation detection equipment, additives for changing the refractive index and density of glass, low-temperature mercury-thallium alloy switches, high-density liquids, alloys, photosensitive devices, and radioactive isotopes for cardiovascular diagnostic procedures. The largest single use in the rest of the world continued to be as an ingredient in rodenticides; however, this use has been banned in the United States.

### PRICES

Metal traders reported that the price of imported thallium metal, 99% pure, was $20 per pound.

### Table 25.—U.S. imports for consumption of thallium in 1985, by country

| Country | Compounds | | | Unwrought and waste and scrap | |
|---|---|---|---|---|---|
| | Gross weight (pounds) | Content[1] (pounds) | Value | Gross weight (pounds) | Value |
| Belgium-Luxembourg | 946 | 757 | $19,698 | 440 | $6,530 |
| Canada | 56 | 45 | 1,700 | 2 | 1,034 |
| France | 771 | 617 | 14,419 | -- | -- |
| Germany, Federal Republic of | -- | -- | -- | 220 | 3,583 |
| United Kingdom | -- | -- | -- | 220 | 3,098 |
| Total | 1,773 | 1,419 | 35,817 | 882 | 14,245 |

[1] Estimated by the Bureau of Mines.

Source: Bureau of the Census.

### Table 26.—U.S. import duties for thallium

| Item | TSUS No. | Most favored nation (MFN) | | Non-MFN |
|---|---|---|---|---|
| | | Jan. 1, 1985 | Jan. 1, 1987 | Jan. 1, 1985 |
| Unwrought metal | 632.50 | 1.3% ad valorem | Free | 25% ad valorem. |
| Compounds | 422.00 | 4.0% ad valorem | 3.7% ad valorem | Do. |

## WORLD REVIEW

**World production data for thallium were not available. However, Western European companies were thought to be the largest producers of thallium in 1985. World reserves of thallium contained in zinc ores were estimated to be 830,000 pounds of thallium.**

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